NOVA

MAX

1|2 A

HAVO|VWO TTO

Physics & Chemistry

NAME AND CLASS:

MALMBERG

1|2 HAVO|VWO TTO Part A

Physics and chemistry

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MAX 2021 release

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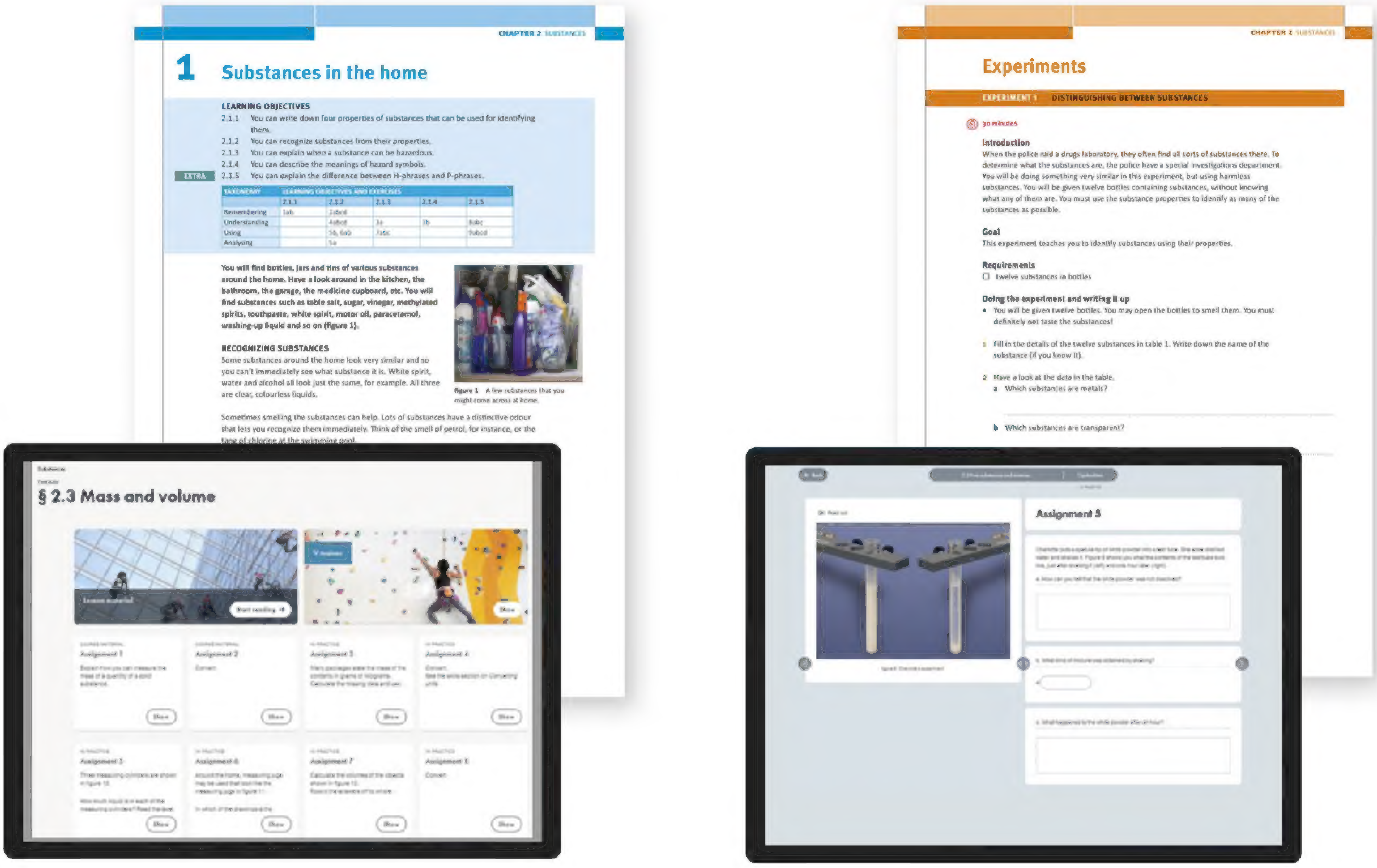

Work in your book *and* work online!

There are two books for each school year plus an online learning environment. Your teacher will decide what you do online (with a laptop, tablet or mobile) and what you do in your book. Each chapter is split up into theoretical sections, experiments, an article about the subject in practice and an overview of the course material. Each section begins by stating the learning objectives that tell you what you will be learning about. You can find additional material at the end of each section. In the *Experiments* section, you will do practical assignments and learn how to study and investigate. At the end of each chapter, there is an *Everyday science* section, an article in which part of the course material is discussed in practice in a situation from daily life or from a scientific context. The closing part contains the *Remember* and *Concepts* sections.

The advantages of working online

- You will see quickly what you are doing correctly and what you are doing wrong.
- You get feedback on your answers straight away.
- You can watch video clips and animated clips.
- You can practice important skills with the Skills Trainer.
- You learn the concepts using the *Flash cards*.
- You can use the *Test yourself* sections, the *Practice test* and the *Diagnostic test* to measure whether you have understood the material.
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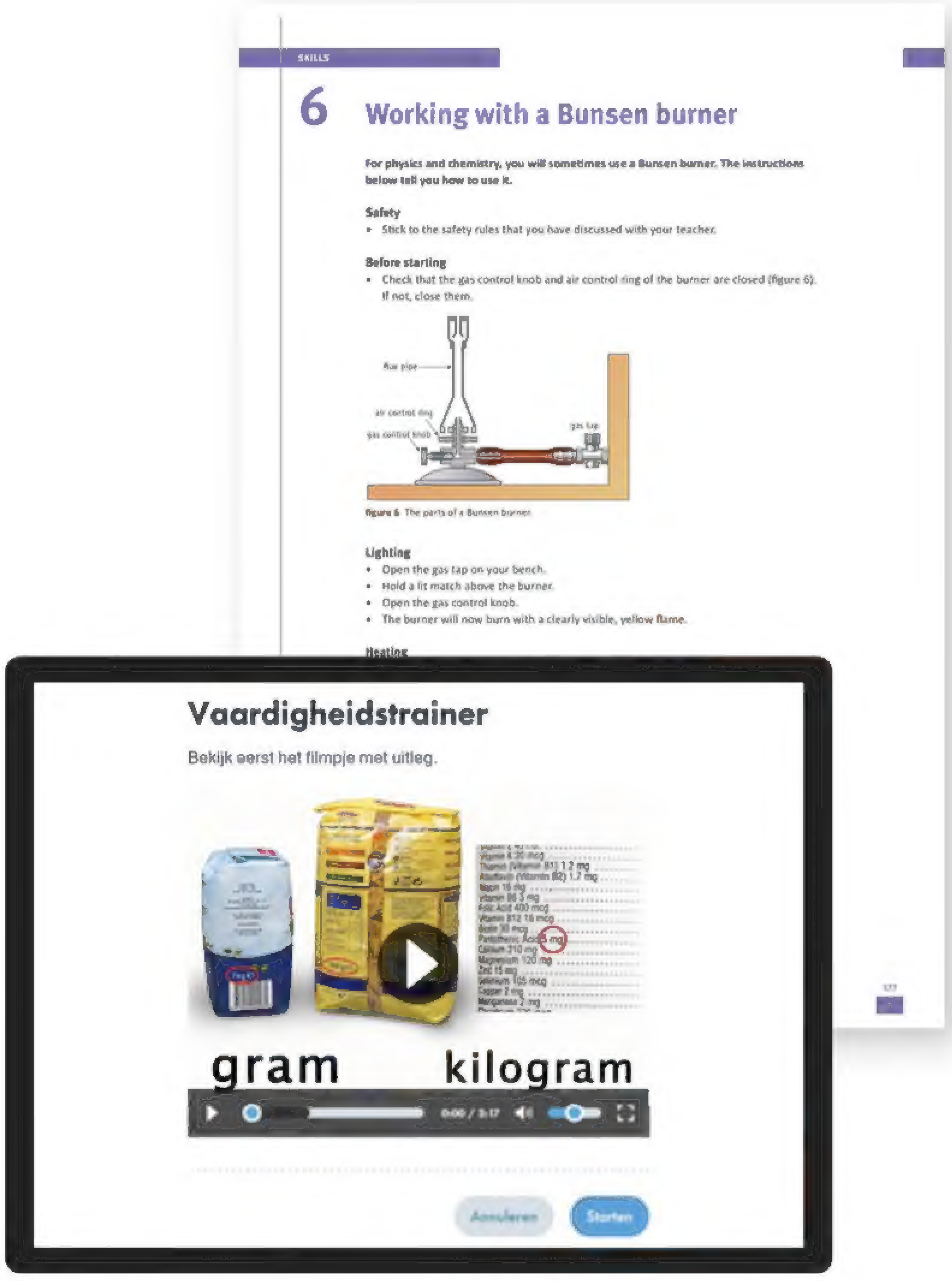
- Your teacher will monitor how you are progressing.

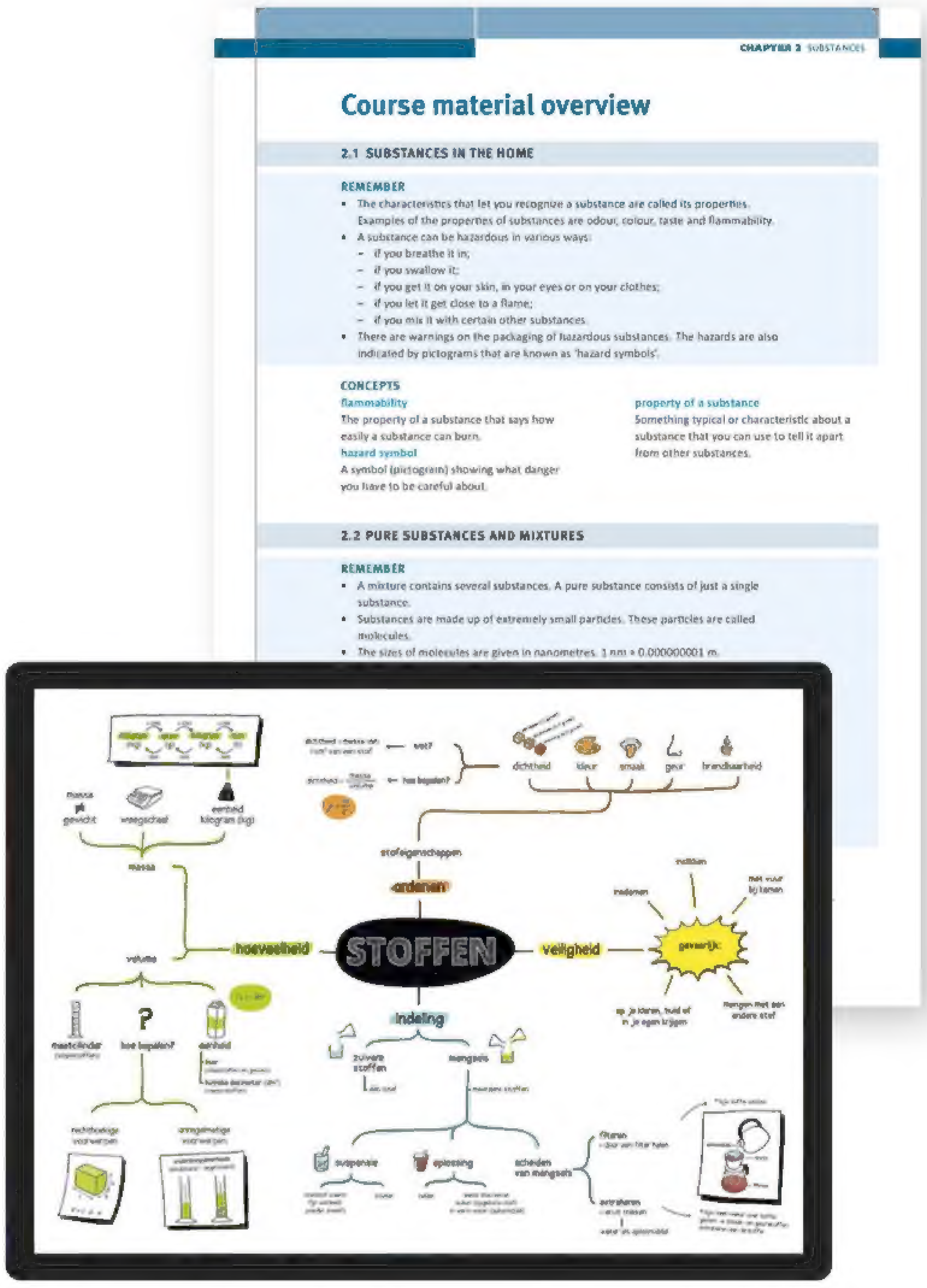
Skills

At the end of each book, you will find a *Skills* section in which the key skills for doing research and investigating are explained. A number of important skills can also be practised online with the Skills Trainer.

Good preparation for the test!

The *Remember* and *Concepts* sections at the end of each chapter in the book will help you prepare for the test. Each chapter ends with an online *Completion* section that contains a *Summary assignment*. This is also where you can find the *Flash cards* for learning all the concepts. There is also a *Diagnostic test*. If you are not sure that you understand the material well enough, you can do the *Test yourself* section or the *Practice test*.





The advantages of the book

- You get a quick overview of what you will be learning.
- You can read the longer texts on paper.
- You can annotate the text and add remarks.
- You will be making drawings and adding colour yourself, which helps you remember the course material better.

Meaning of the symbols

go to the online learning environment for some useful extras

EXP. 1 there is an experiment for this classroom materia

use the skills for this assignment

this is how long this experiment will take you

this assignment is extra challenging

Contents Part A

Contents Part B

1 Natural sciences

DISCOVERING AND INVESTIGATING

Physicists and chemists have made all kinds of discoveries by carrying out research. To do research – to investigate things – you need to be able to make measurements using measuring instruments. Without the discoveries and research done by physicists and chemists, we would not have phones, medicines and LED lights, for instance.


Where does electricity
Experiment

1 A new subject

LEARNING OBJECTIVES

1.1.1 You can describe what the natural sciences are about.
1.1.2 You can use examples to explain the difference between physics and chemistry.
1.1.3 You can explain how X-rays are used.

TAXONOMY	LEARNING OBJECTIVES AND EXERCISES		
	1.1.1	1.1.2	1.1.3
Remembering	1	2abc	3ab
Understanding		4, 5abcd, 7a	9abc
Using		6, 7b	9d, 10
Analysing		8	11

Back in prehistoric times, people wore bearskins. They slept in caves and communicated with each other using smoke signals and tom-toms (drum signals). Thanks to natural sciences, we have good clothing nowadays, and comfortable houses and modern communications equipment such as phones and computers.

SCIENCE

Physics is a **science.** But what is science, exactly? Science is about gaining knowledge and then using that knowledge in everyday life. There are lots of different sorts of sciences because you can gain knowledge in all kinds of different fields. Physics is one of the subjects in **natural sciences**, as are **chemistry** and **biology.** They are called natural sciences because they involve studying nature. In biology, you study living nature – the world of plants, animals and the human body. In physics and chemistry, you study non-living nature. This could for instance be:

- what makes lightning happen (figure 1);
- generating electricity using solar panels (figure 2);
- how candlewax melts;
- the braking distance of a moped;
- why nails rust (figure 3).

figure 1 Lightning in a storm.

figure 2 Solar panels on the roof of a house.

figure 3 Rusty nails.

Natural sciences are also about natural phenomena such as the weather, earthquakes, volcanoes, solar eclipses and so forth.

WILHELM CONRAD RÖNTGEN

Natural scientists have made major contributions to modern society. One example of a natural scientist who did that is Wilhelm Conrad Röntgen (figure 4).

figure 4 Wilhelm Conrad Röntgen (1845-1923).

In 1895, the physicist Röntgen discovered a mysterious type of radiation that was invisible and could pass straight through paper and cardboard. Röntgen discovered that the bones in your body were able to block a substantial fraction of those rays, whereas other parts of the body let them pass through almost unaffected.

When the radiation falls on your hand, for instance, a sort of shadow image is created behind your hand. There is a lot of shadow behind the bones and only a little behind the muscles (figure 5). Röntgen discovered that he could take photographs of those shadow images: he produced the first **X-ray photographs.** On an X-ray, the parts of the body that absorb a lot of the X-ray radiation are white. X-rays are harmful to your body.

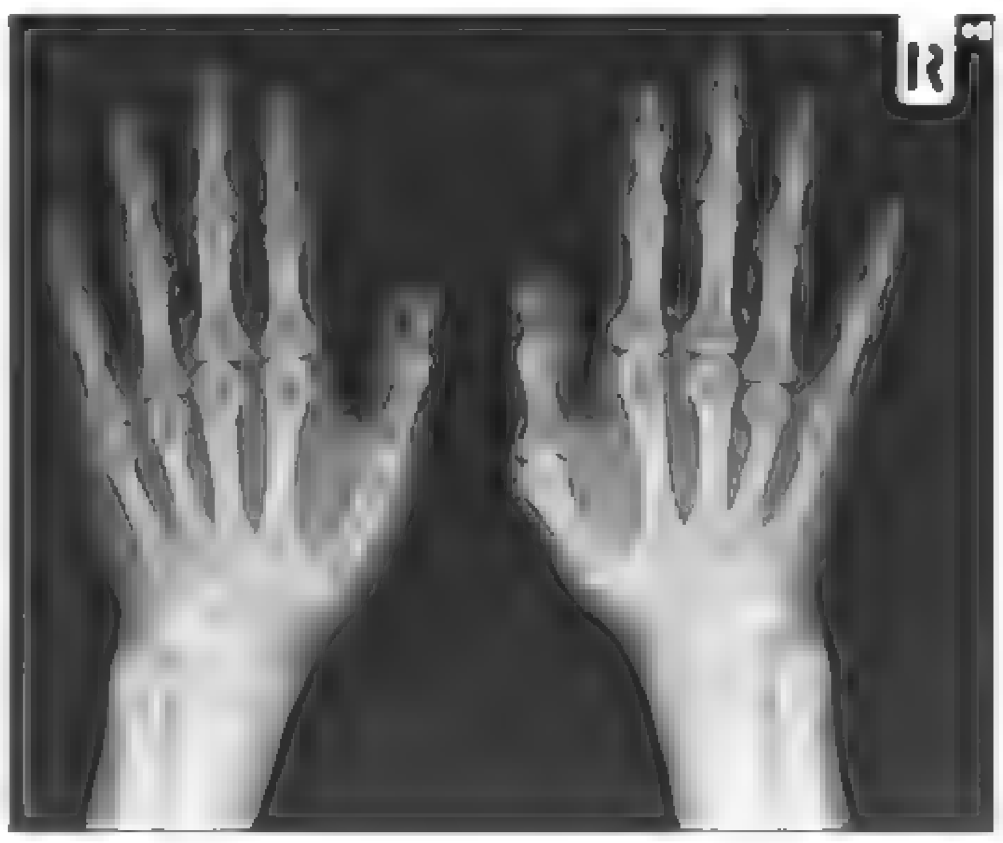


figure 5 An X-ray photograph of two hands.

CHANGES

Substances and objects can change. If you heat a metal rod, it will expand and get longer. If you cool the rod down again, it will shrink and go back to its original length. On a hot summer day, the Eiffel Tower can be as much as 30 cm taller than in the winter. But when the weather is cold, the Eiffel Tower shrinks again. So these changes are temporary.

You think of water as a liquid. Wet washing contains water. If you hang the washing out to dry, the water changes into water vapour that escapes from the washing. And the washing dries. In freezing cold weather, water changes into ice (figure 6). So liquid water can change into water vapour or into ice. That type of change is called a state change (or phase change). But you can change water vapour and ice back into liquid water. So these are temporary changes too.

There are other ways for substances to change, though. If you burn wood, it turns into charcoal, ash and smoke (figure 7). You can't turn charcoal, ash and smoke back into wood. The wood has been changed forever into other substances. So this is a permanent change.

figure 6 Water can change into ice.

figure 7 Wood changes into charcoal, ash and smoke.

In chemistry and physics, you study changes in non-living nature. The big difference is that physical changes are temporary and chemical changes are permanent. So a rod getting longer when it is heated or liquid water changing into water vapour or ice are studied in physics, whereas burning wood is studied in chemistry.

Practice the concepts using the *Flash cards*.

COURSE MATERIAL

1 Physics and chemistry are about *living* / *non-living* nature.

2 When you light a candle, the candlewax changes from a solid into a liquid.

a Explain whether this would be studied in biology, physics or chemistry.

b Some birds spend the winter in the Netherlands but others migrate to warmer countries in the autumn.
Explain whether this would be studied in biology, physics or chemistry.

c A substance changes into other substances.
Explain whether this would be studied in biology, physics or chemistry.

3 Choose the correct words.

a X-rays are mostly absorbed by your body's *bones* / *muscles*.

b When X-rays fall on your hand, a sort of shadow image is created behind your hand. There is a lot of shadow behind the *bones* / *muscles*. There is not much shadow behind the *bones* / *muscles*.

IN PRACTICE

4

Which subjects do the following belong to?

- How sound is produced would be studied in *biology* / *physics* / *chemistry*.
- A blooming flower would be studied in *biology* / *physics* / *chemistry*.
- An egg hardening when boiled would be studied in *biology* / *physics* / *chemistry*.
- Why a block of wood floats but a block of iron sinks would be studied in *biology* / *physics* / *chemistry*.

5

Explain whether the following changes are physical or chemical.

a Tin or another metal melting.
b A plastic chair bends when a heavy person sits on it.
c Frying potatoes in a pan.
d The coil in a heater glows red when the heater is switched on.

6

A new copper roof has been put on a building (figure 8a). A few years later, the effects of the rain and air have turned the copper green (figure 8b). This is called oxidation. Oxidation would be studied in *physics* / *chemistry* because the copper on the roof *has* / *has not* changed into another substance.

figure 8 A historic building with a copper roof.

ⓐ

ⓑ

7

Have a look at figure 9.

a What changes when you pull on a spring?
b Explain that this can be a temporary change or a permanent one.

figure 9 Pulling on a trampoline spring.

★ 8 Sometimes several changes can happen at the same time.
What changes when an iron nail is heated with a Bunsen burner?

9 Figure 10 shows you an X-ray of a man's neck and part of his head.

a Which absorbs more X-rays: the muscles or the bones?
b What has this man got in his throat?
c What will that object be made of?
d Does that material absorb a lot of X-rays or not very much?

figure 10 An X-ray photograph that was taken at a hospital.

10 Rolina has broken her leg. An X-ray of the fracture is taken in hospital.
Why do they use as little X-ray radiation as possible for this?

11 X-rays are not only used in hospital.
What does security at an airport use X-rays for?

Test what you know with *Test yourself*.

2 Research

LEARNING OBJECTIVES

1.2.1 You can explain what the scientific method is.
1.2.2 You can explain how you can make observations safely during an experiment.
1.2.3 You can describe what units and variables are.
1.2.4 You can explain what an indicator is.

TAXONOMY	LEARNING OBJECTIVES AND EXERCISES			
	1.2.1	1.2.2	1.2.3	1.2.4
Remembering	2	1		3
Understanding	5abcdef, 7b	4	8ab	
Using	7ace		9	10
Analysing	6, 7d			

In physics and chemistry, you sometimes investigate to get an answer to a study question. This is doing research using the scientific method. During the research, you have to make observations and measurements.

DOING RESEARCH

EXP 1

A physical or chemical study is done in several steps.

- A study always starts with a **study question** (also known as a **research question**). That describes what you are trying to find out. Examples of such a study question could be: What is the temperature of boiling water? How far does a bicycle travel after you stop pedalling?
- Then you think up a possible answer to the study question for the time being. What do you think the result might be? A provisional answer like this is called a **hypothesis**. It may only be a guess, but the hypothesis is usually based on something: the expected result.
- After formulating the hypothesis, you think up an experiment that will give a result that answers the research question.
- Then you carry out that experiment.
- You show the measured results clearly in a table and/or graph.
- You then use the results of the experiment to try to answer the study question. You can then see whether the hypothesis was correct or not.

This way of working is called the **scientific method**.

SENSING

EXP 2

When you do an experiment, you have to observe closely what happens. Observations are made using your **senses** (figure 1). Your senses let you see, hear, smell, touch and taste.

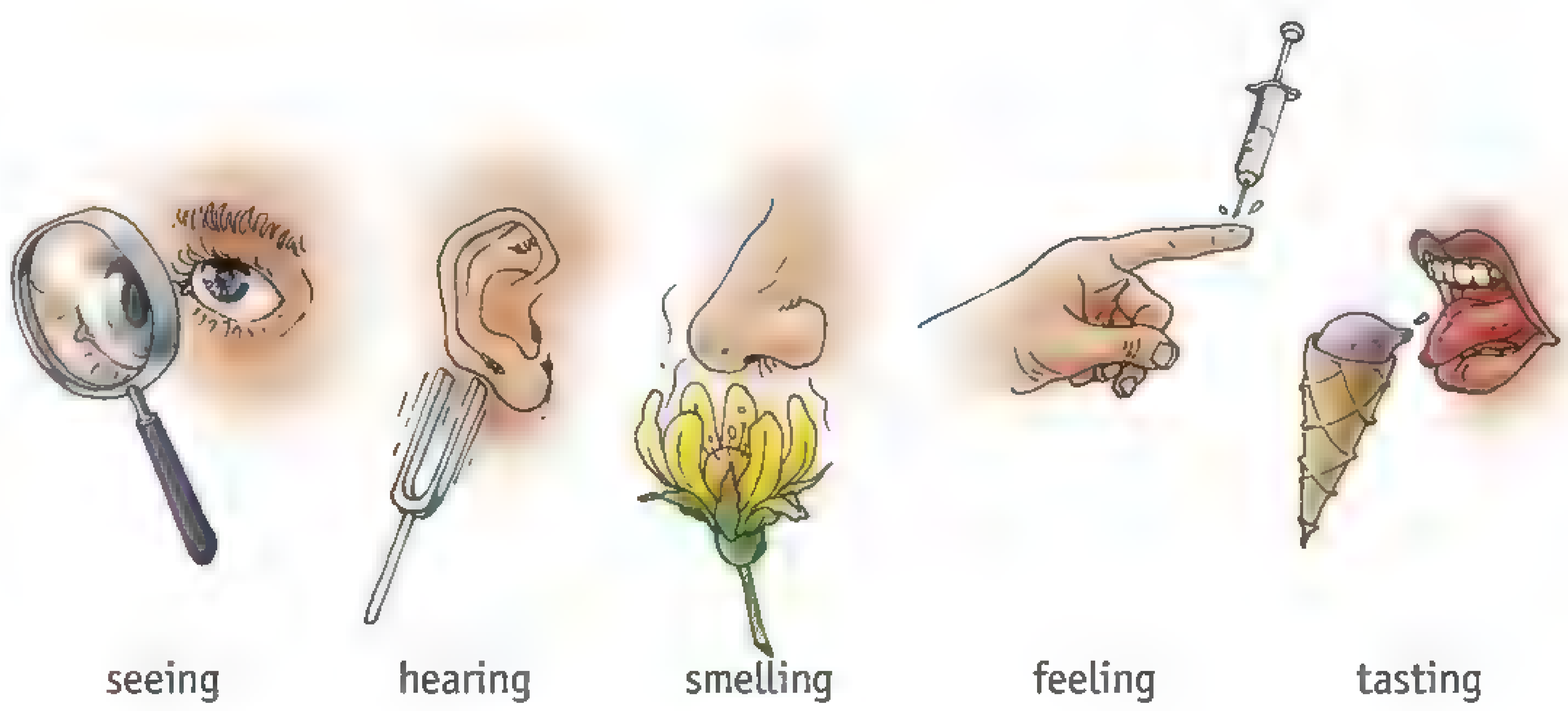


figure 1 Observations are made using your senses.

You are always able to hear, see and touch in investigations. The vapours of some substances are poisonous. If you breathe in poisonous vapours, it can make you sick or damage your lungs. So you should never just take a big sniff a substance: you should always do it carefully. Some substances are toxic (poisonous). They could make you seriously ill. So you should never taste substances!

You can observe things with your senses, but that isn't particularly accurate. If you hang a block weighing 50 grams from a rubber band, you can see that the rubber band stretches. But you can't simply see how much longer. If you want to know that, you have to make measurements. You do that using **measuring instruments**.

VARIABLES, UNITS AND MEASURED VALUES

If you go and stand on the scales, you may for instance read off the number 52. You might then say, "I weigh fifty-two." That's not right in physics, though. Everyone will understand that you weight 52 kilograms and not 52 grams or 52 tons. But in physics, you need to add the indicator kilograms (abbreviated to kg) after the number. The kilogram is a **unit**. A unit is a quantity or size that is used for expressing things. The unit is what gives the number its meaning. The unit is always written after the number. The number 52 is the **measured value**.

You can use various units for time, for instance such as minutes, hours, days or weeks. Those are all units of time. Length has its own units as well. Melissa's height (that's a length) could be 154 centimetres. The distance across the schoolyard (that's a length) could be 30 metres.

Time and length are things you can measure. Time and length are examples of variables. A **variable** is a property that you can measure. Every variable has its own units.

Scales let you determine the mass of an object or of a quantity of a substance. The mass is the amount of substance, expressed in grams (g) or kilograms (kg). Objects with a lot of mass are heavy; objects without much mass are light.

A soft drink is a liquid. You can measure how much coke there is in a glass: you are then measuring the volume of the drink. The volume is the space that an object or a quantity of a substance takes up. You express volumes in cubic metres (m^3), cubic decimetres (dm^3) or cubic centimetres (cm^3). Volumes can also be given in litres (L) or millilitres (mL).

INVESTIGATIONS USING AN INDICATOR

EXP [illegible]

Laboratories use indicators. An **indicator** lets you investigate whether a specific substance is present or not. The indicator changes colour under the influence of that substance. There are indicators for sugar, alcohol, starch, carbon dioxide and so forth. The indicator used for starch is iodine, a yellow-brown liquid (figure 2).

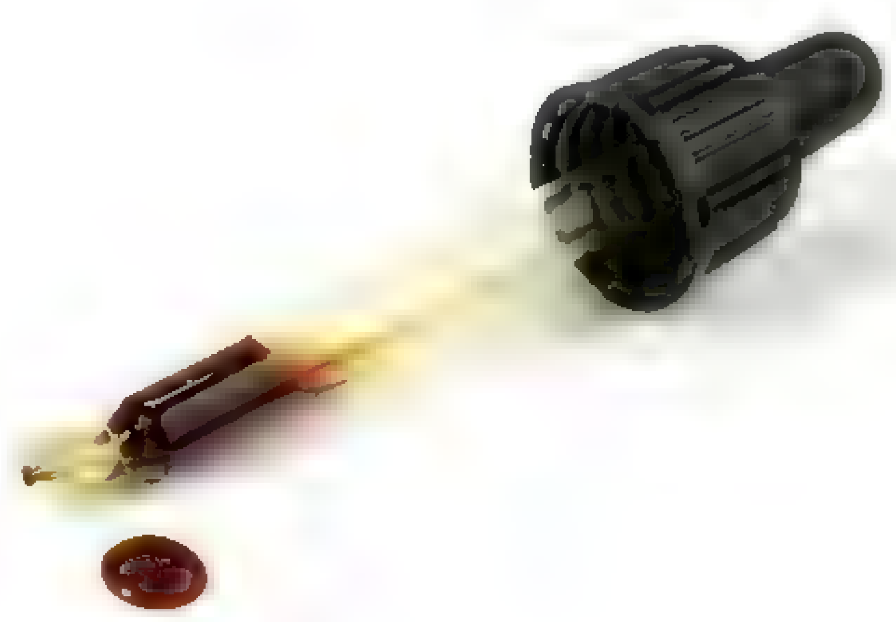


figure 2 Iodine.

You can now use that fact in the scientific method:

- The question you are studying is "Is there starch in a slice of white bread?"
- The hypothesis could be "No, there is no starch in a slice of white bread."
- The experiment is then set up as follows: Let a few drops of iodine fall on a slice of white bread.
- Then carry out the experiment (figure 3). You can see that the slice of bread turns dark blue there.
- You can now answer the study question: "Yes, there is starch in a slice of white bread." The hypothesis was incorrect.

figure 3 Bread contains starch.

Practice the concepts using the *Flash cards*.

COURSE MATERIAL

1 Why should you never taste a substance in physics or chemistry?

2 Which unit belongs with which variable?

A	length ○	○ 1	kilogram
B	mass ○	○ 2	litre
C	time ○	○ 3	metre
D	volume ○	○ 4	second

3 Insert the correct words into the text.

An .... lets you find out whether a specific substance is present or not.

The .... changes .... under the influence of that substance.

If you add .... to starch, the colour of the iodine changes from yellow-brown to ....

IN PRACTICE

4 You use your senses to make observations.
Which sense are you using?

A hearing ○		○ 1 skin	
B taste ○		○ 2 nose	
C smell ○		○ 3 eyes	
D touch ○		○ 4 ears	
E seeing ○		○ 5 tongue	

5 Does each of these sentences belong with the study question or the conclusion of a piece of research?

a	Can electricity pass through a plastic tube?	*study question / conclusion*
b	Who is the tallest person in this class?	*study question / conclusion*
c	The sun rises in the east every day.	*study question / conclusion*
d	Serge wants to know how high the classroom ceiling is.	*study question/ conclusion*
e	Paper burns more easily than wood.	*study question / conclusion*
f	Nick is the tallest person in the class.	*study question / conclusion*

6 See the skills section on *Doing research*.
Read figure 4 closely.
Think up a research question yourself that would suit this text.

Evelyn cycles to school on her new e-bike. She doesn't yet know how fast the e-bike actually goes. Is it quicker than her normal bike? She's going to find out. She hopes that she won't get stuck partway because the battery has gone flat. When she gets to school, her friend Raymond asks how long it took her. Evelyn doesn't know – she had only been concentrating on cycling as fast as possible.

figure 4 Evelyn on her e-bike.

7 When Vera stops pedalling, her bike goes slower and slower until she comes to a halt. Vera wants to know whether she keeps going for equally long on a tarmac path or a dirt track. The distance that she goes from the moment she stops pedalling is called the rolling distance.

a Write down the study question for this description.
b Think up a hypothesis for this study question.
c Why does she need a bike with a speedometer?
d Vera is going to do an experiment to let her answer her study question.
Describe the experiment she has to carry out.
e At 15 kilometres an hour, Vera's rolling distances are 37 m on the tarmac path and 25 m on the dirt track.
Answer the study question (in other words, draw your conclusion).

8 See the skills section on *Working with variables and units*.

a Underline the variable in each of these sentences.
The swimming pool is 25 metres in length.
The time Jurgen needs for cycling home is 15 minutes.
The temperature in a fridge is generally 4 degrees Celsius.
The width of a tennis court is 8.23 metres.
The mass of the cauliflower is 600 grams.

b Underline the unit in each of these sentences.
If you have a temperature of 39 degrees Celsius, you have a fever.
A football match has two halves of 45 minutes.
Anna competes at judo in the 52 kilogram weight class.
In hockey, the penalty spot is 6.4 metres from the goal.
If the air pressure drops below 1013 hectopascals, it is likely to rain.

9 What is actually missing on the road sign in figure 5?

figure 5 A traffic sign.

10 The police used to use a breathalyser to check if a driver had been drinking.
What substance could the police detect using a breathalyser?

Test what you know with *Test yourself*.

3 Experiments

LEARNING OBJECTIVES

1.3.1 You can recognize the equipment used in the experiments.
1.3.2 You can explain what various measuring instruments are used for.
1.3.3 You can explain the difference between digital and analogue equipment.
1.3.4 You can list the safety rules and safety equipment used in the experiments.
1.3.5 You can explain how a Bunsen burner works.
1.3.6 You can list the three types of flames you get from a Bunsen burner and their characteristics.

TAXONOMY	LEARNING OBJECTIVES AND EXERCISES					
	1.3.1	1.3.2	1.3.3	1.3.4	1.3.5	1.3.6
Remembering	1			2	3	
Understanding			4	5abcdefg, 7		
Using				8b		8a
Analysing		10ab		6	9	

When you are going research in physics or chemistry, you do experiments in which you use measuring instruments. During these experiments, there are safety rules that you must stick to at all times.

PRACTICAL EQUIPMENT

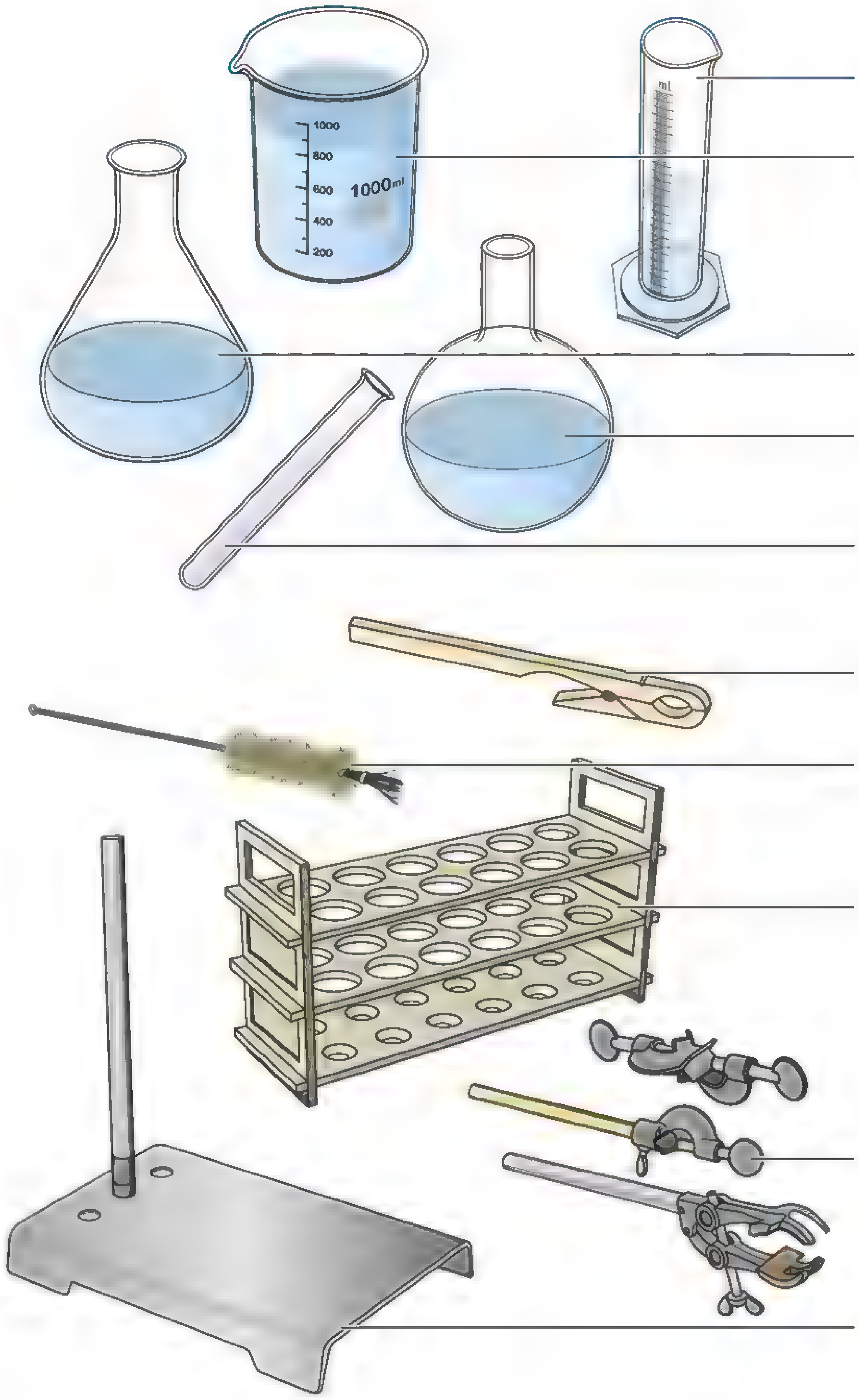
Carrying out practical activities in physics and chemistry lessons is called an **experiment**. In an experiment, you investigate a natural phenomenon. You generally need measuring instruments for that and you often need other things too. The things that you use in a practical activity are referred to as experimental equipment. There are lots of different kinds of equipment for experiments (figure 1).

MEASURING INSTRUMENTS

You measure time using a clock or a stopwatch. Time can be expressed in units of seconds (s), minutes (min), hours (h) or even years (y).

You can measure length with a ruler, a drafting protractor or a measuring tape (figure 2). Use the item that is most suitable for the length you are going to measure. Lengths can be expressed in centimetres (cm). metres (m) or kilometres (km).

You measure temperature with a thermometer. Mass is measured using measuring scales. (In physics, you use the word mass rather than weight.)



picture	name	application
	measuring cylinder	for measuring quantities
	glass beaker	for mixing and heating liquids
	conical flask	for heating liquids
	round-bottomed flask	for heating liquids
	test tube	for mixing liquids chemistry tests
	test tube tongs	for holding a test tube while it is being heated
	test tube brush	for cleaning test tubes after use
	test tube rack	for storing test tubes
	retort stand rod/clamps	for fixing things in place
	retort stand	for assembling retorts

figure 1 Equipment for experiments.

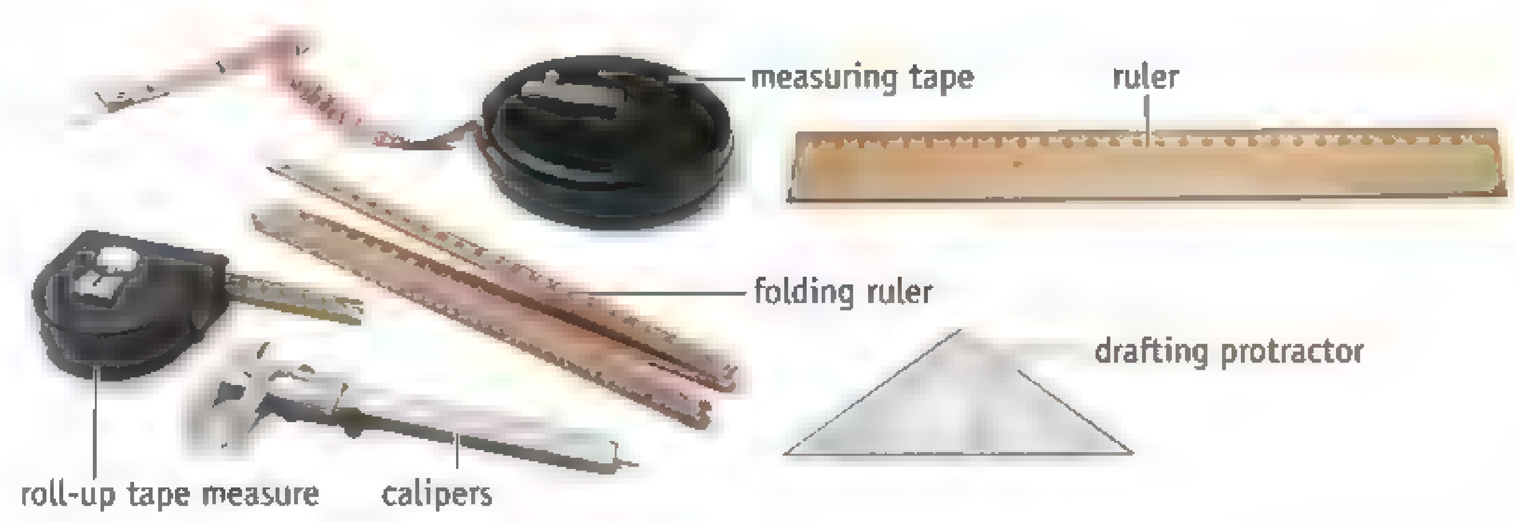


figure 2 Measuring instruments for measuring length.

Figure 3 shows you two thermometers. The oven thermometer (figure 3a) has a pointer that rotates along a **graduated scale.** The scale is made up of regularly spaced marks next to a series of numbers that let you read off the measured value. Measuring instruments with a pointer and a graduated scale are called **analogue** instruments. The clinical thermometer (figure 3b) shows the measurement on a small screen. A measuring instrument with numbers on a display is called a **digital** instrument.

figure 3 Two thermometers.

ⓐ analogue thermometer

ⓑ digital thermometer

SAFETY

During an experiment, you may sometimes work with fire or dangerous substances. You may sometimes work with electricity too. If anything goes wrong, somebody could get hurt. So safety is very important. You must always do experiments carefully. So you have to observe the **safety rules** (figure 4).

figure 4 Safety is important during experiments.

The safety rules are:
- Listen to your teacher and do what they say.
- Don't shove or pull people or run about in the classroom.
- Never eat or drink anything in the classroom.
- Don't leave bags or other things lying around where people have to walk.
- Wear safety goggles when needed.
- Tie long hair back if you are working with fire.
- Always work carefully, particularly with chemicals.
- Only sniff unknown substances very cautiously.
- Never taste substances.
- If anything goes wrong, you should warn your teacher at once.

In experiments, you need to know what the safety features and devices are. The following safety equipment is present in most practical labs:
- a fire extinguisher that can be used to put out a fire that is just starting;
- a fire blanket that you can wrap someone in if their clothing catches fire (figure 5);
- an eye shower or eye rinsing bottle that can be used to wash your eye clean if a corrosive substance gets in it;
- an emergency shower that you can stand under if you have had a corrosive substance spilled over you;
- an emergency exit, a door that is intended as an escape route from the classroom;
- an emergency stop, a red-and-yellow button that cuts of the gas and electricity when pressed (figure 6).

Your teacher will tell you where the safety equipment is in the classroom. They will also tell you how to use it.

figure 5 Practicing with a fire blanket.

figure 6 The emergency stop.

THE BUNSEN BURNER

EXP. 6

Experiments sometimes require you to heat something up. You do that with a Bunsen burner. A Bunsen uses natural gas. It is attached to a gas tap by a hose. There is a **gas control knob** on the Bunsen burner (figure 7) that you use to allow more or less gas into it. That makes the flame larger or smaller. You can also close the gas control knob completely.

Natural gas can only burn if oxygen gets to it. There is oxygen in air. The air gets into the gas through the **air control ring** (figure 7). You use the air control ring to allow more or less air in to the gas. The gas and air are mixed together in the **barrel** so that the flame at the top of the barrel will burn well.

You must always light the Bunsen in the same way:

1 Close the air control ring.
2 Check that the gas control knob is closed.
3 Open the gas tap on your bench.
4 Hold a burning match just above the top of the barrel.
5 Open the gas control knob a little so that the Bunsen burns with a yellow-orange flame.

You turn the Bunsen off as follows:

1 Close the air control ring.
2 Close the gas tap on your bench.
3 Close the gas control knob.

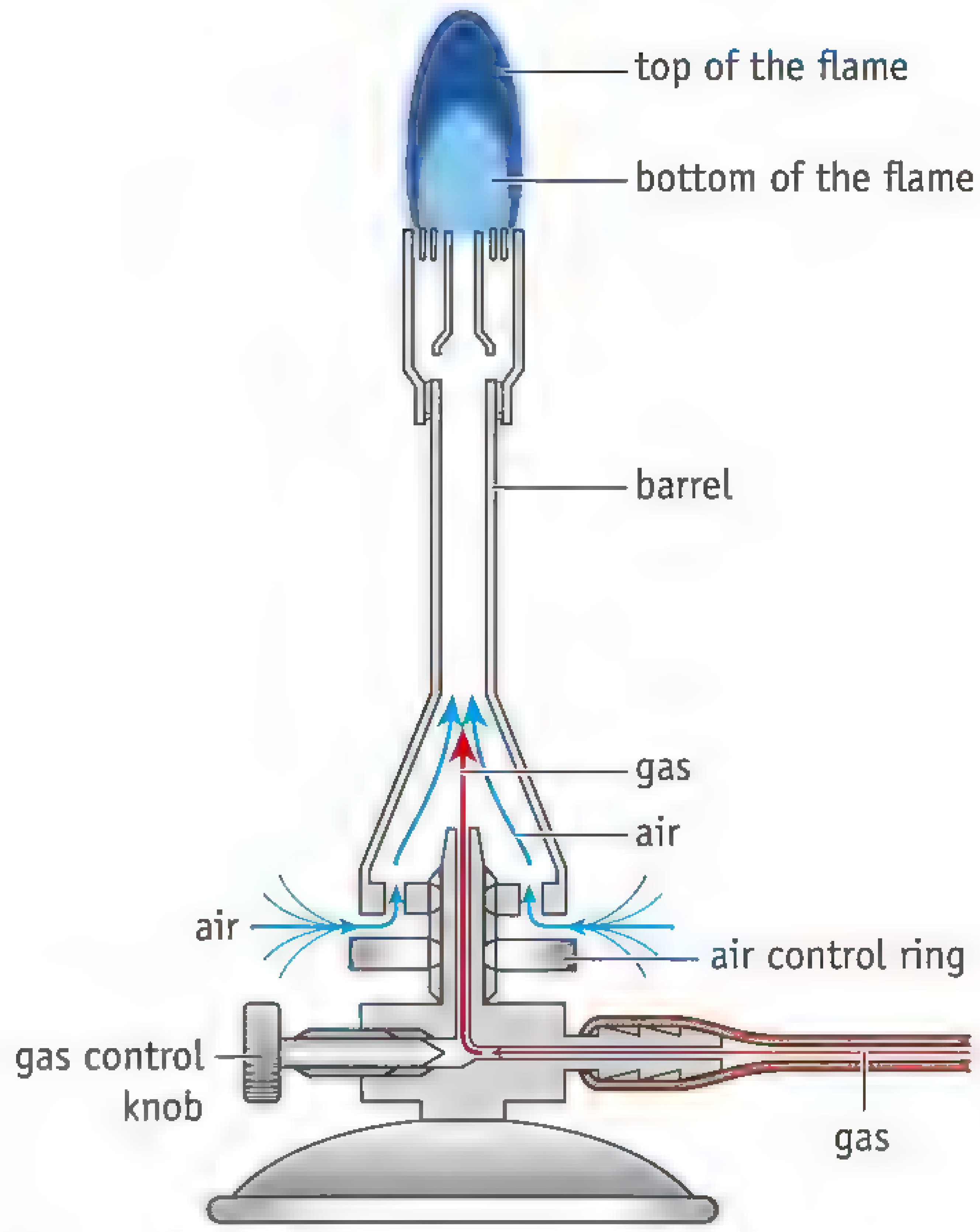


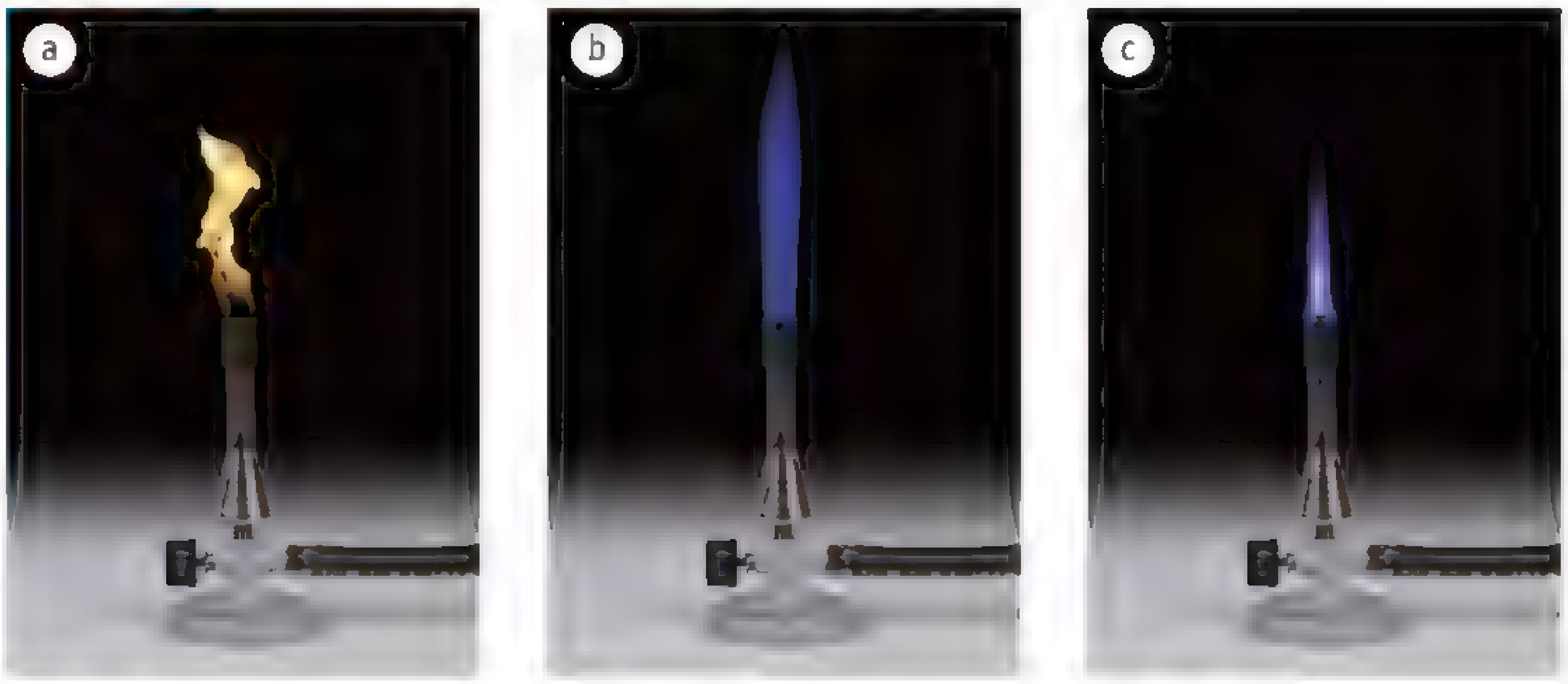
figure 7 The parts of a Bunsen burner.

THREE FLAMES

There are three kinds of flame you can make with the Bunsen burner:

- A **luminous flame** or **yellow flame** (figure 8a) is what you use if you don't need the Bunsen for a moment. The yellow flame is easily visible so that you won't burn yourself on it by mistake. To get a yellow flame, you have the gas control knob open just a little and the air control ring is closed. The yellow flame is the least hot of the three types. You should never use the yellow flame when you are heating a glass beaker or a test tube. This is because the yellow flame does not burn the gas completely. Soot remains, which then blackens the glass beaker or test tube. It is then difficult to get them clean again.
- The **silent blue flame** or **still blue flame** (figure 8b) is used if you have to keep something hot. You also use the silent blue flame if you are only heating a small amount of a liquid, for instance a little bit of water. To get a still blue flame, you open the gas control knob and the air control ring a little bit. The silent blue flame is much hotter than the yellow flame.
- The **roaring blue flame** (figure 8c) is very hot. A roaring blue flame is mostly invisible. You can only see the blue cone or heart, but the flame is in fact much bigger than that. You use the roaring blue flame when you are heating a large amount of liquid, for instance boiling a litre of water. To get a roaring blue flame, you open the gas control knob and the air control ring wide.

figure 8 Three different flames from a Bunsen burner.



yellow flame (luminous flame)

silent blue flame

roaring blue flame

Practice the concepts using the *Flash cards*.

COURSE MATERIAL

1 Figure 9 shows four items of equipment for experiments that are all made of glass. Write down the name of each piece of glassware.

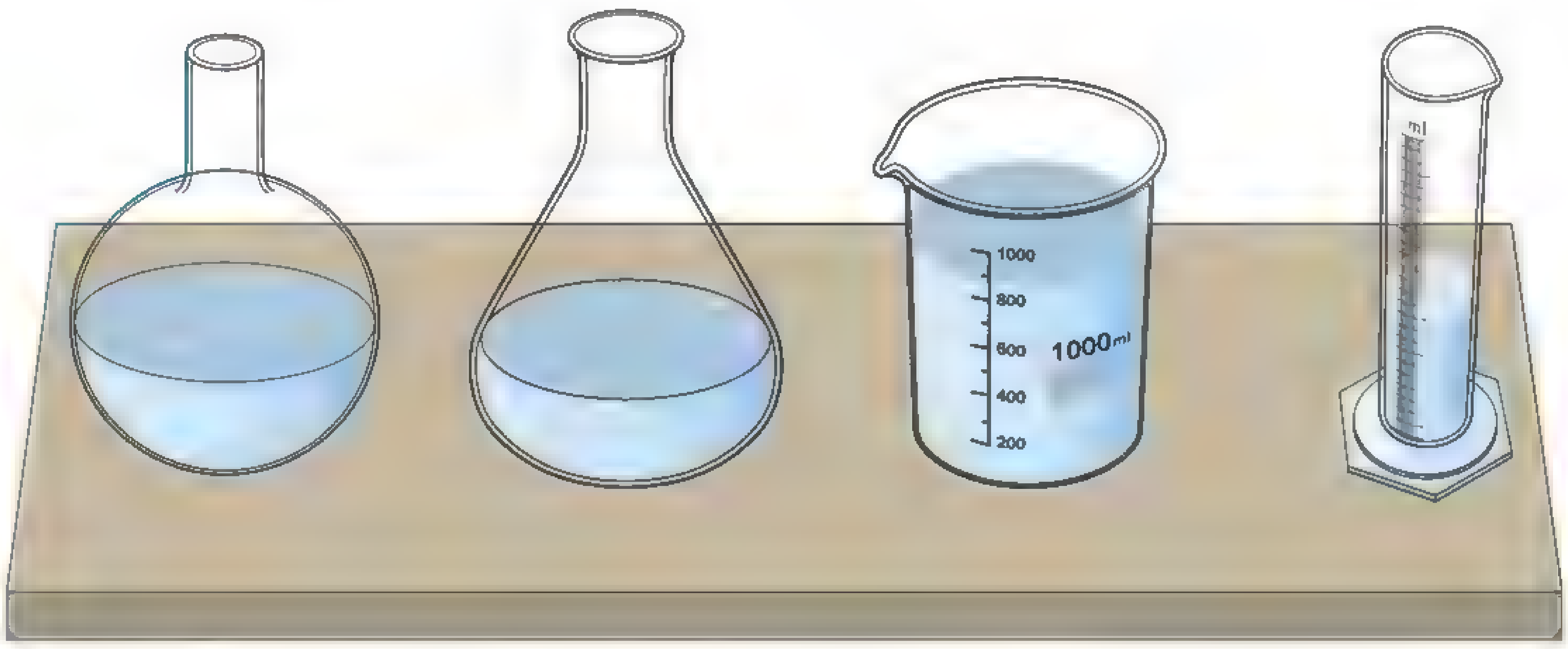


figure 9 These items are used in a lot of experiments.

1 ....

2 ....

3 ....

4 ....

2 There are various safety rules for experiments.
Write down three safety rules.

3 When you are lighting a Bunsen burner, the air control ring must be *open / closed*.

4 Have a look at figure 10.
Which clock is analogue and which is digital? Explain how you can see that.

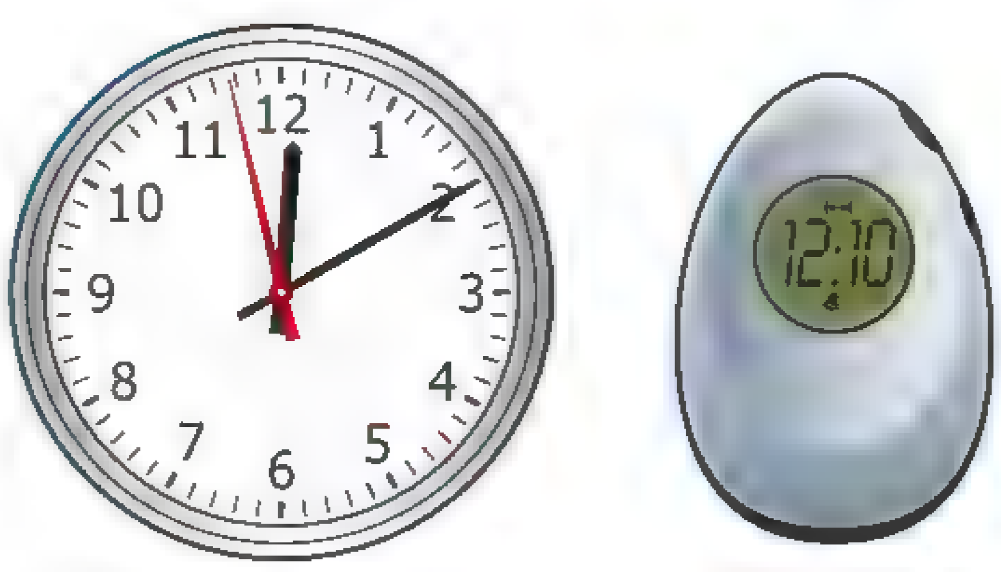


figure 10 Two different clocks.

IN PRACTICE

5

Read the sentences about things you could do in an experiment.
Write down whether what is happening is correct or incorrect.

a	Kylie puts her nose up against a bottle to sniff what's in it.	*correct / incorrect*
b	Ranjev is holding the test tube in a flame using the test tube tongs.	*correct / incorrect*
c	Carl takes his safety goggles off while he is heating a liquid.	*correct / incorrect*
d	Karen has long hair that she has tied into a ponytail hanging down her back.	*correct / incorrect*
e	Elaine slides her bag under the bench before she starts on the experiment.	*correct / incorrect*
f	Paul tastes a substance to see if it is sweet.	*correct / incorrect*
g	Sarah leaves the practical lab for a talk with her mentor, so she turns the Bunsen burner down to a yellow flame.	*correct / incorrect*

6

Chloe accidentally knocks over her Bunsen burner. The Bunsen's flame stays alight. Chloe panics but you stay calm because you know the right thing to do first.

- ○ A You turn off the gas tap on her bench.
- ○ B You pour a glass of water over the Bunsen.
- ○ C You take the fire extinguisher and use it to put the Bunsen burner out.
- ○ D You take hold of the Bunsen and put it the right way up again.
- ○ E You try to comfort Chloe.

7

Write down five safety features in the practical lab in your school.

8

In an experiment, you will be heating two glass beakers of water, one containing 100 mL water and the other containing 2 L. You have to measure the temperature every 30 s using a thermometer. You make a graph of each series of measurements, plotting the temperature against the time.

a Which flame do you use in the following situations?
- First you heat the glass beaker with 100 mL water.
- You make a graph of the measurements for the small glass beaker.
- You heat the large glass beaker with 2 L water.
- You make a graph for the large glass beaker with 2 L water.

b Why do you have to be very careful when heating the small glass beaker of water in particular?

★ 9

Natural gas needs oxygen to burn. When the Bunsen burner is being lit, the air control ring is closed so that no air can flow through the barrel along with the gas.
Explain why it is still possible to light the Bunsen.

★ 10

John has two identical candles.

a Explain how he can make a clock from one of them, using the other.
b What are the disadvantages of this candle clock?

Test what you know with *Test yourself*.

Experiments

EXPERIMENT 1 CARRYING OUT RESEARCH

10 minutes

Introduction

You carry out an experiment when you want to find out something that you do not yet know.

Goal

In this experiment, you will formulate a research question and a conclusion for an experiment.

Requirements

☐ ruler or drafting protractor

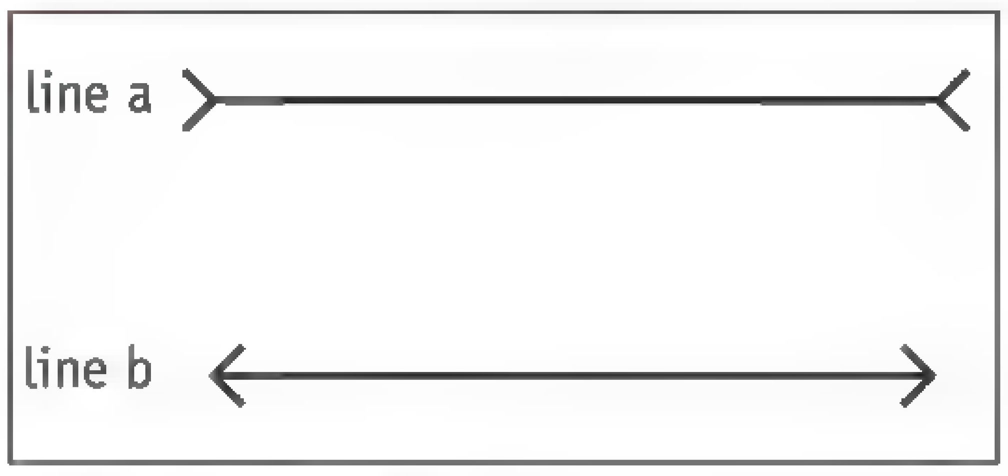


figure 1 Two lines.

Doing the experiment and writing it up

- Have a look at the two lines in figure 1. The arrowheads don't count as part of the lines (they aren't included in the length).

1 Think of a study question for these two lines.

....

....

2 You're only allowed to look to start with – don't measure them.
What is your hypothesis for the lengths of the two lines?
- ○ A Line (a) is longer.
- ○ B Line (b) is longer.
- ○ C Lines (a) and (b) are the same length.

- Take a ruler or drafting protractor and measure the lengths of the lines.

3 What is the conclusion from your study?

....

....

4 Say whether your hypothesis was correct or not.

....

....

EXPERIMENT 2 TESTING THE SENSE OF TEMPERATURE

15 minutes

Introduction

You can't use your fingers very well to determine the temperature. In this experiment, you will see that your hands can each feel that the same temperature is different.

Goal

In this experiment, you will be investigating how accurate your sense of temperature is.

Requirements

- ☐ 3 glass beakers
- ☐ warm water

Doing the experiment and writing it up

- Fill glass beaker A two thirds full with warm water.
- Fill glass beaker B two thirds full with lukewarm water.
- Fill glass beaker C two thirds full with cold water.
- Put two fingers of your left hand in glass beaker A. At the same time, put two fingers of your right hand in glass beaker C (figure 2).
- After 1 minute, take your fingers out of glass beakers A and C. Then put them in glass beaker B straight away.

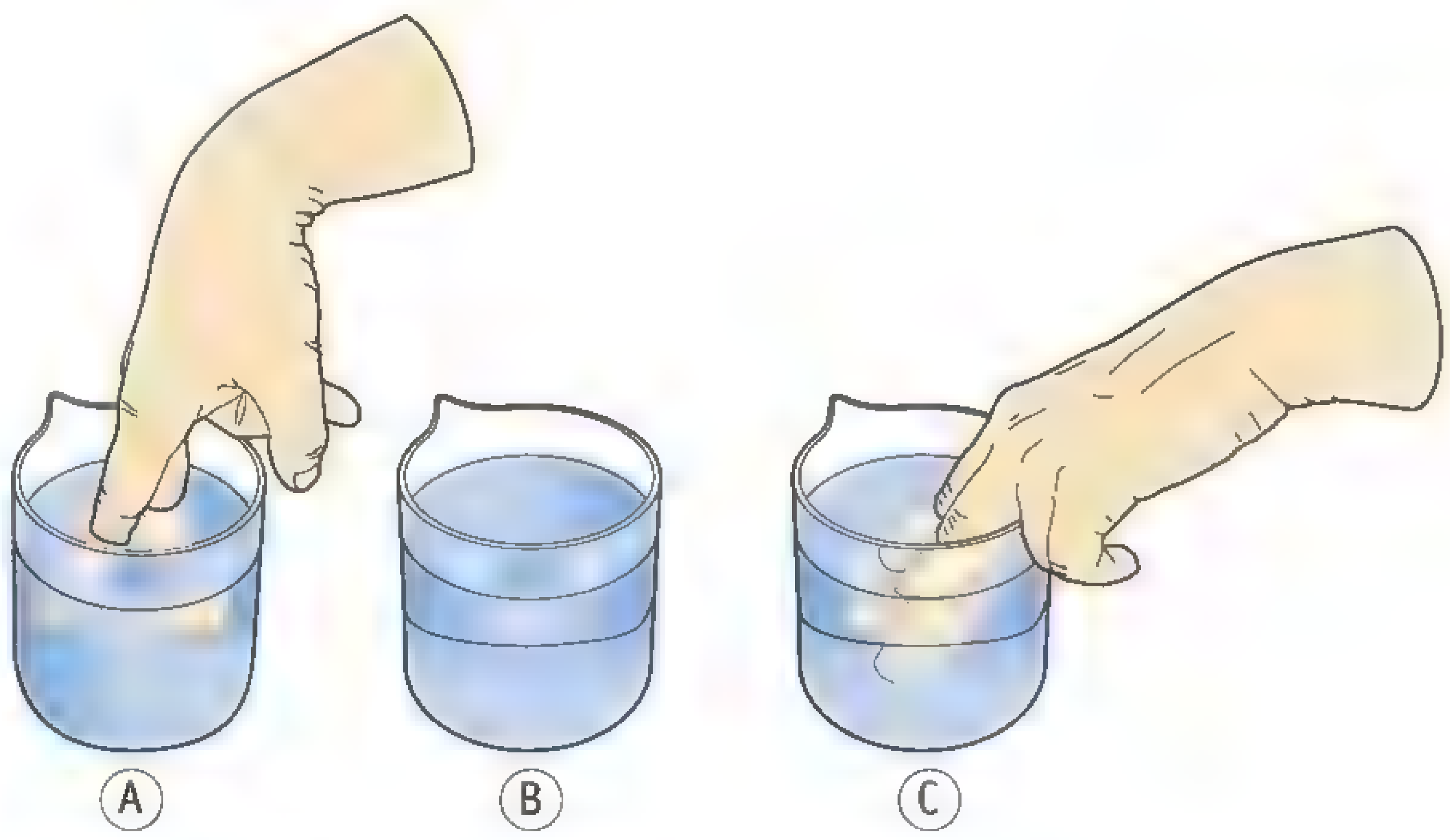


figure 2 Testing your sense of temperature.

1 What does the water in glass beaker B feel like?

- ○ A left hand cold, right hand cold
- ○ B left hand cold, right hand warm
- ○ C left hand warm, right hand cold
- ○ D left hand warm, right hand warm

2 What do you now know about how accurate your sense of temperature is?

....

....

....

EXPERIMENT 3 AN INDICATOR FOR ACIDS

15 minutes

Introduction
Red cabbage juice can be used to show if a liquid is acidic. You add a little juice to the liquid and see what colour you get. If the juice turns red, the liquid is acidic. If the juice stays a bluish purple, the liquid is not acidic.

Goal
You are going to investigate whether five liquids are acidic or not, without tasting them.

Requirements
- ☐ red cabbage juice
- ☐ test tube
- ☐ 5 unknown liquids
- ☐ pipette

Doing the experiment and writing it up
- Fill the test tube a quarter full with liquid 1.
- Use the pipette to add a few drops of red cabbage juice.

1 What do you see?

....

....

2 Write "yes" in the second column of table 1 if the liquid is acidic and "no" if it isn't.

table 1 Are the liquids acidic?

number	acid?	name of liquid
1		
2		
3		
4		
5		

- Investigate the other four liquids in the same way.

3 Complete the rest of the second column of the table.

- Your teacher will tell you what substances you have been examining.

4 Write down the names of the liquids that you have investigated in the third column of the table.

5 Which of these liquids would you not have expected to be acids?

....

....

EXPERIMENT 4 SHOWING THE PRESENCE OF CARBON DIOXIDE

10 minutes

Introduction
Limewater lets you show whether there is carbon dioxide gas in your breath.

Goal
You are going to demonstrate that there is carbon dioxide in the air you breathe out.

Requirements
- ☐ limewater
- ☐ glass beaker
- ☐ straw

Doing the experiment and writing it up
- Fill the glass beaker half full with limewater.
- Blow gently and carefully through the straw into the limewater.

1 What do you see?

....

....

2 Complete:

.... lets you demonstrate that there is .... in your breath. The limewater then goes ....

3 Which substance is the indicator here?

....

4 You have actually already done the experiment. Every experiment should in fact begin with a study question. When you look back at it, what study question could you have asked here?

....

....

EXPERIMENT 5 WORKING WITH TEST TUBES

15 minutes

Introduction
If you are going to do experiments, you have to learn techniques that let you use the equipment correctly.

Goal
This experiment teaches you two ways of using a test tube correctly.

Requirements
- ☐ 2 test tubes
- ☐ test tube rack
- ☐ permanent marker
- ☐ ruler or drafting protractor
- ☐ water spray bottle
- ☐ cleaning cloth
- ☐ table salt

Doing the experiment and writing it up
- Take the two test tubes from the rack.
- Dry the outsides of the test tubes thoroughly with a cloth.
- Mark a thin line on each test tube 4 cm from the bottom.
- Fill one test tube precisely to the mark with water directly from the tap.
- Fill the other test tube precisely to the mark with water from the spray bottle.

1 You have to fill a test tube precisely to a mark.
Which is the more accurate way to do that?
- ○ A Filling it from the tap.
- ○ B Filling it from a spray bottle.
- ○ C The tap and the spray bottle are equally accurate methods.

- Put a little table salt in both test tubes. The amount of salt must approximately the same in each.
- Take hold of a test tube with water and salt by the top. Hold the test tube in place with your thumb and index finger.
- Now shake the test tube carefully back and forth (figure 3).
- Keep shaking it until the salt has dissolved.

2 Has the salt in the tube that you were not shaking dissolved as well? *yes / no*

3 Shaking makes substances dissolve more *quickly / slowly*.

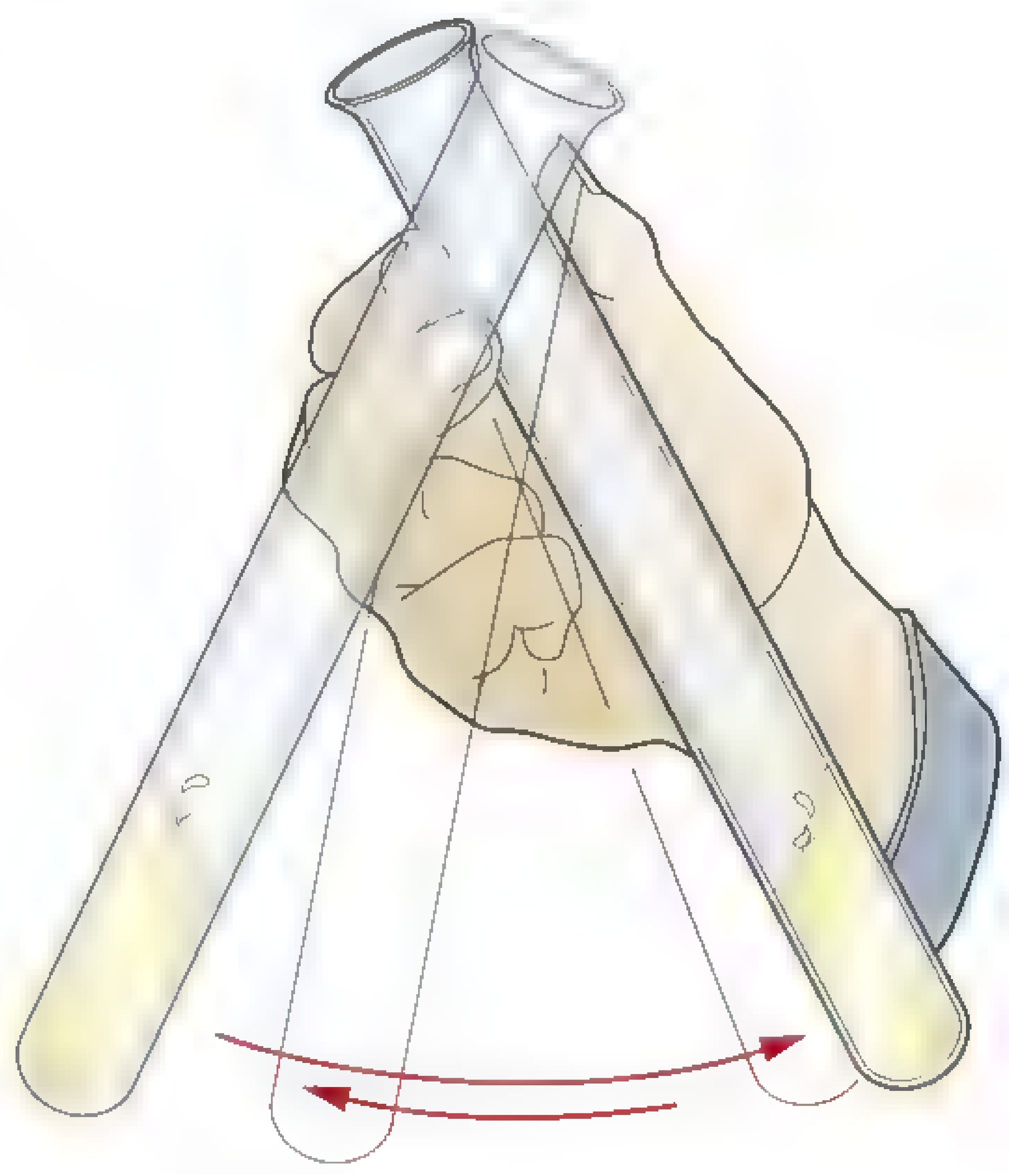


figure 3 Shaking a test tube.

EXPERIMENT 6 WORKING WITH A BUNSEN BURNER

30 minutes

Introduction
In your experiments at school, you will often be using a Bunsen burner to heat things. You always have to be careful when you use a gas burner.

Stick to the safety rules that you have discussed with your teacher.

Goal
In this experiment, you will learn about the properties of a gas flame and how to work with a Bunsen.

Requirements
- ☐ gas burner (Bunsen burner)
- ☐ wire mesh
- ☐ wooden test tube rack
- ☐ matches/lighter

Doing the experiment and writing it up
See the skills section on *Working with a Bunsen burner.*

- Check that the gas control knob and the air control ring on the burner are closed (figure 4).
- Open the gas tap on your bench.
- Hold a burning match above the Bunsen and open the gas control knob a little.

1 What colour is the flame of the burner?

....

- Open the air control ring a little.

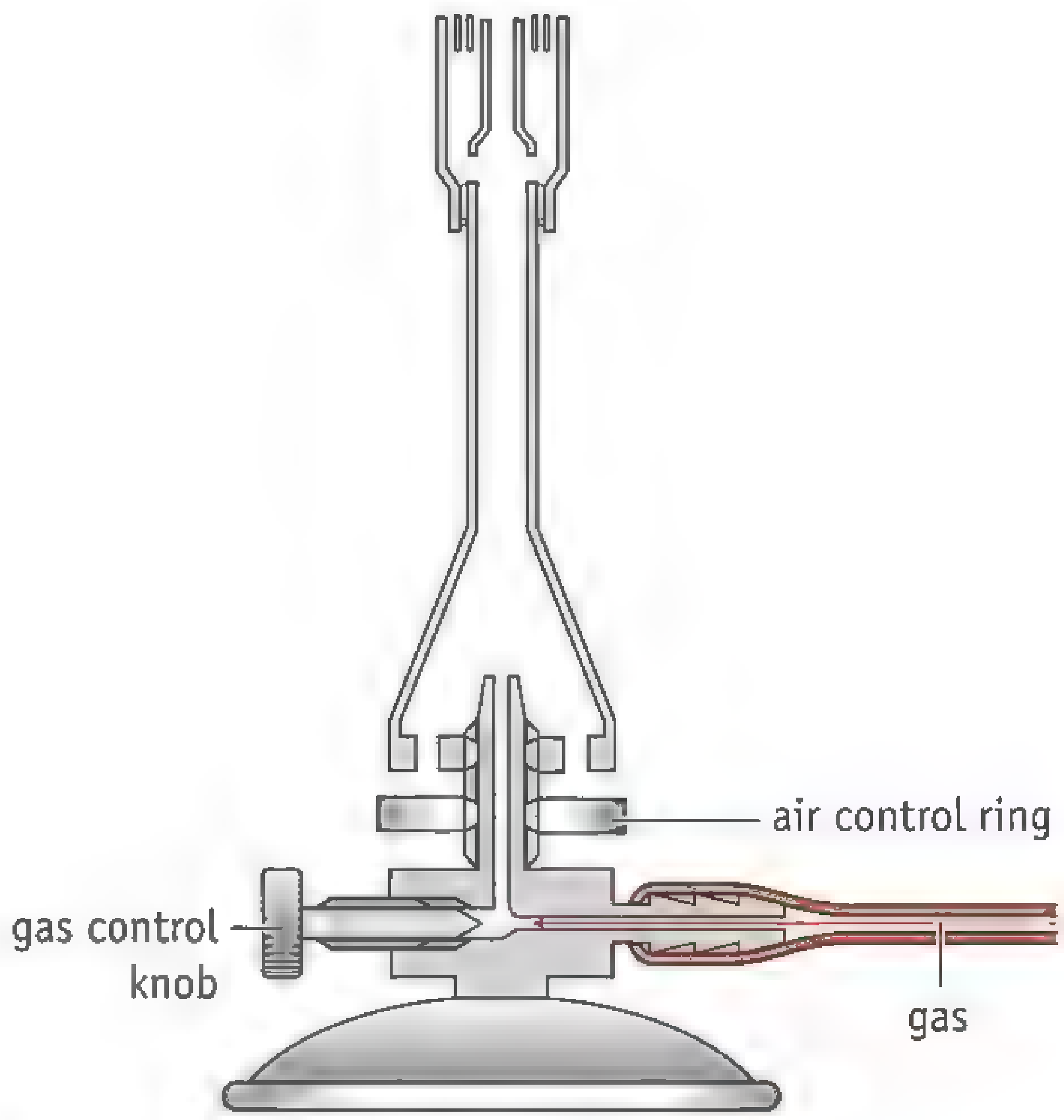


figure 4 A Bunsen burner.

2 What happens to the colour of the flame?

....

- Now open the air control ring a good bit further.

3 What happens to the colour of the flame?

....

4 What can you hear?

....

- Hold the wire mesh vertically in the flame (see figure 5).

5 Draw and colour in what you see in figure 5.

- Hold the wire mesh horizontally in the flame (see figure 6):
  a first for thirty seconds in the blue heart of the flame;
  b then for thirty seconds just above the blue heart of the flame;
  c finally for thirty seconds at the top of the flame.

6 Draw and colour in what you see in figure 6.

7 Where is the flame hottest? How can you see that?

....

- Close the air control ring.
- Close the gas tap on your bench.
- Close the gas control knob.

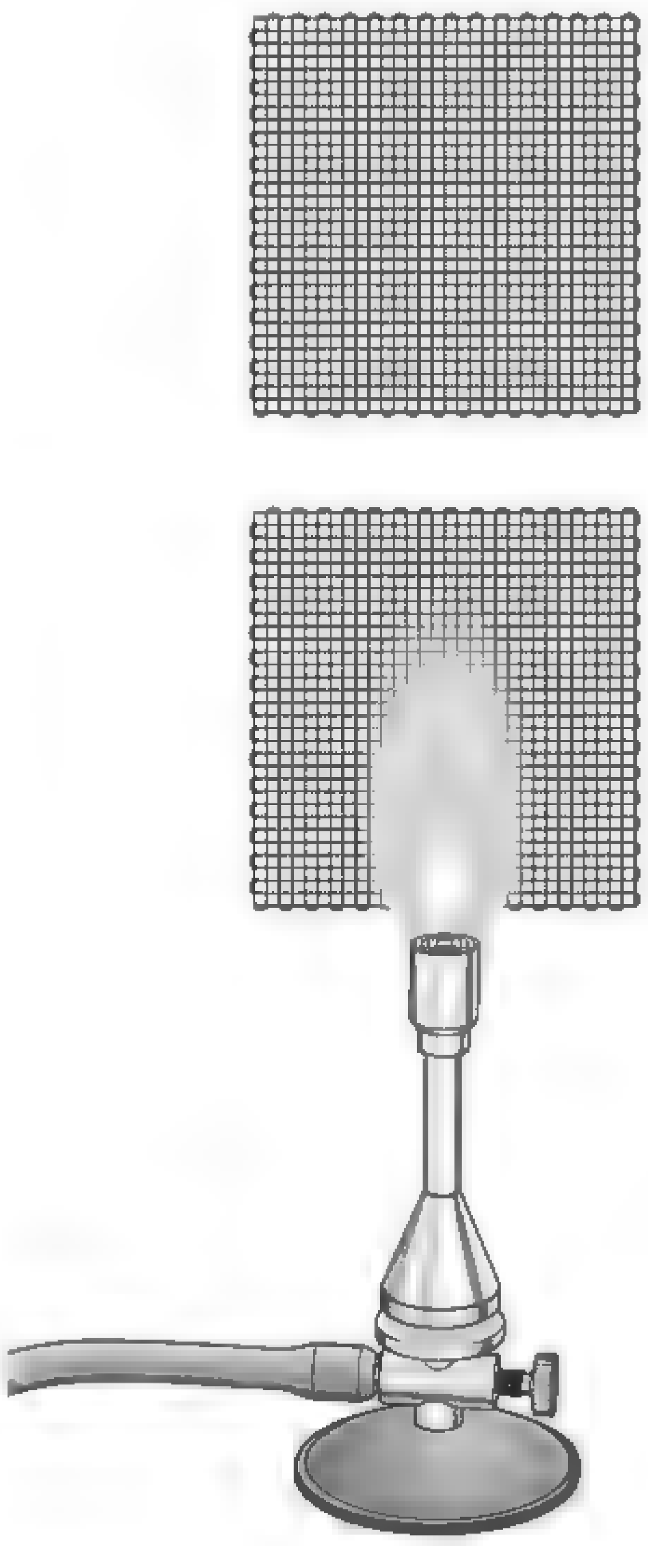


figure 5 The wire mesh held vertically in the flame.

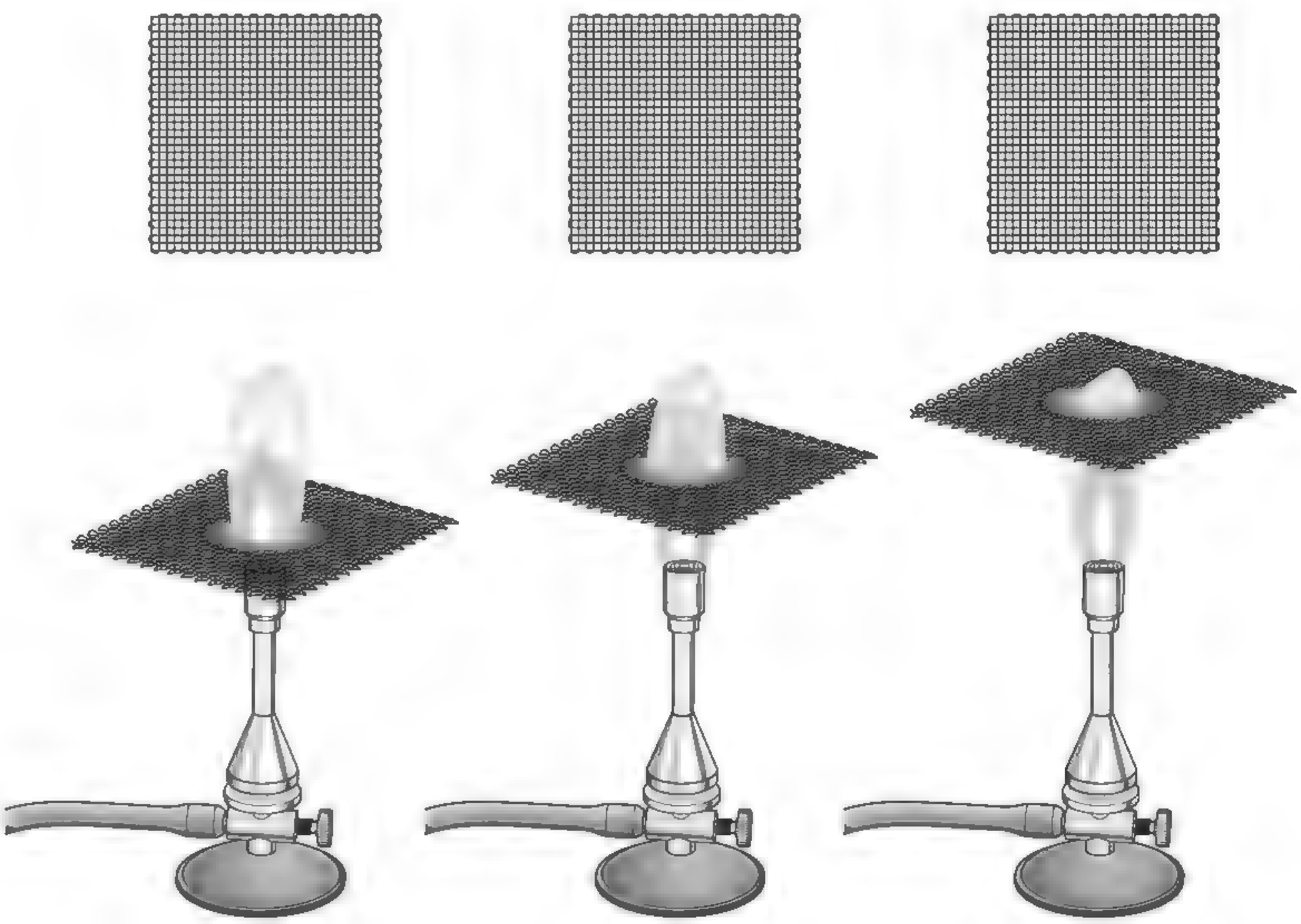


figure 6 The wire mesh held horizontally in the flame.

Course material overview

1.1 A NEW SUBJECT

REMEMBER

- Science is about gaining knowledge and then using that knowledge in our everyday lives.
- Biology, physics and chemistry are natural sciences:
  - biology studies living nature;
  - physics studies temporary changes in non-living nature;
  - chemistry studies permanent changes in non-living nature in which substances change into other substances.
- The physicist Röntgen discovered rays that are invisible and that can go straight through some substances. He made the first X-ray photographs of body parts.

CONCEPTS

biology
School subject in which living nature is studied.

chemistry
School subject in which permanent changes in non-living nature are studied.

natural sciences
Sciences that study nature.

physics
School subject in which temporary changes in non-living nature are studied.

science
Gaining knowledge and then using that knowledge in everyday life.

X-ray photographs
Photographs that are made using X-rays. They are widely used for detecting breaks in bones.

1.2 RESEARCH

REMEMBER

- Research in physics and chemistry is done using the scientific method. This consists of several steps:
  - asking a study question;
  - thinking of a hypothesis;
  - thinking up an experiment;
  - carrying out the experiment;
  - showing the measurement results as a table and/or graph;
  - answering the study question.
- A variable is a property that you can measure. A measurement consists of a measured value and a unit. A unit is a size that is used for expressing things.
- Examples of variables are length, time, mass and volume.
- The mass is the amount of substance, expressed in grams or kilograms. The volume shows the amount of space that an object or a quantity of a substance takes up.
- An indicator lets you investigate whether a specific substance is present or not. The indicator changes colour under the influence of that substance.

CONCEPTS

hypothesis
An answer for the time being, predicting what you think will happen.

indicator
A substance that can be used for demonstrating the presence of another.

measuring instrument
Tools for making measurements.

measurement value
The number that is determined by the measurement.

scientific method
Doing research according to a fixed sequence of steps.
sensory organ
Part of your body that you can use to perceive things.
study question
What you are trying to find out in the research.
unit
A size used for expressing things.
variable
A property that you can measure.

1.3 EXPERIMENT

REMEMBER

- An experiment is about carrying out experiments using equipment.
- You must always do experiments carefully, so you have to observe the safety rules.
- When you are doing an experiment, you must make your observations and measurements using measuring instruments.
- An analogue measuring instrument shows the measured value with a needle or pointer on a graduated scale. The scale that an analogue measuring instrument uses is made up of regularly spaced marks next to a series of numbers that let you read off the measured value.
- A digital measuring instrument shows the measured value as numbers on a screen.
- In physics and chemistry, your use a Bunsen burner to heat substances.
- There are three kinds of flame you can make with the Bunsen burner:
  - The luminous flame (yellow flame) is used when you do not need the burner for a little while. This is the least hot flame. You must never use it for heating a glass beaker or test tube because there is soot in the flame.
  - You use the silent blue flame if you are only heating a small amount of a liquid or if you have to keep something hot. This is a hot flame.
  - The roaring blue flame is very hot. Much of this flame is invisible: you can only see the cone-shaped blue heart. You use this flame when you are heating a large amount of liquid.

CONCEPTS

air control ring
The part of a Bunsen burner that you use for letting more or less air in with the gas.
analogue (measuring instrument)
Measuring instrument with a pointer and a graduated scale.
barrel
The tube of a Bunsen burner above the air control ring, in which the air and gas mix.
digital (measuring instrument)
Measuring instrument with numbers on a display.
experiment
Carrying out experiments in physics and chemistry.
gas control knob
The part of a Bunsen burner that you use for letting more or less gas into the burner.
graduated scale
Regularly spaced marks next to a series of numbers that let you read off the measured value.
roaring blue flame
The hottest flame from a Bunsen burner, which you can hear.
safety rules
Rules that you must stick to during an experiment.
silent blue flame
The blue flame of a Bunsen burner that you cannot hear.
yellow flame, luminous flame
The yellow-orange flame of the Bunsen burner.

Go to the *Flash cards* and the *Diagnostic test*.

2 Substances

WORKING WITH DIFFERENT SUBSTANCES

You use substances every day: you put sugar in your tea, wash your hair with shampoo, rinse a glass out with water, spray deodorant on your skin and so forth. And you clean your windows using ammonia, methylated spirits or vinegar. Before you can work with substances, you have to be familiar with their properties.

1 Substances in the home

LEARNING OBJECTIVES

2.1.1 You can write down four properties of substances that can be used for identifying them.
2.1.2 You can recognize substances from their properties.
2.1.3 You can explain when a substance can be hazardous.
2.1.4 You can describe the meanings of hazard symbols.
EXTRA 2.1.5 You can explain the difference between H-phrases and P-phrases.

TAXONOMY	LEARNING OBJECTIVES AND EXERCISES				
	2.1.1	2.1.2	2.1.3	2.1.4	2.1.5
Remembering	1ab	2abcd			
Understanding		4abcd	3a	3b	8abc
Using		5b, 6ab	7abc		9abcd
Analysing		5a			

You will find bottles, jars and tins of various substances around the home. Have a look around in the kitchen, the bathroom, the garage, the medicine cupboard, etc. You will find substances such as table salt, sugar, vinegar, methylated spirits, toothpaste, white spirit, motor oil, paracetamol, washing-up liquid and so on (figure 1).


figure 1 A few substances that you might come across at home.

RECOGNIZING SUBSTANCES

Some substances around the home look very similar and so you can't immediately see what substance it is. White spirit, water and alcohol all look just the same, for example. All three are clear, colourless liquids.

Sometimes smelling the substances can help. Lots of substances have a distinctive odour that lets you recognize them immediately. Think of the smell of petrol, for instance, or the tang of chlorine at the swimming pool.

But you do have to be careful: some substances can irritate the mucous membranes of the nose and lungs. So be careful when smelling something: take the top off the bottle, wave your hand gently back and forth above the neck and sniff just a little bit of the vapour (figure 2). That will make sure you don't inhale too much of an irritant substance.

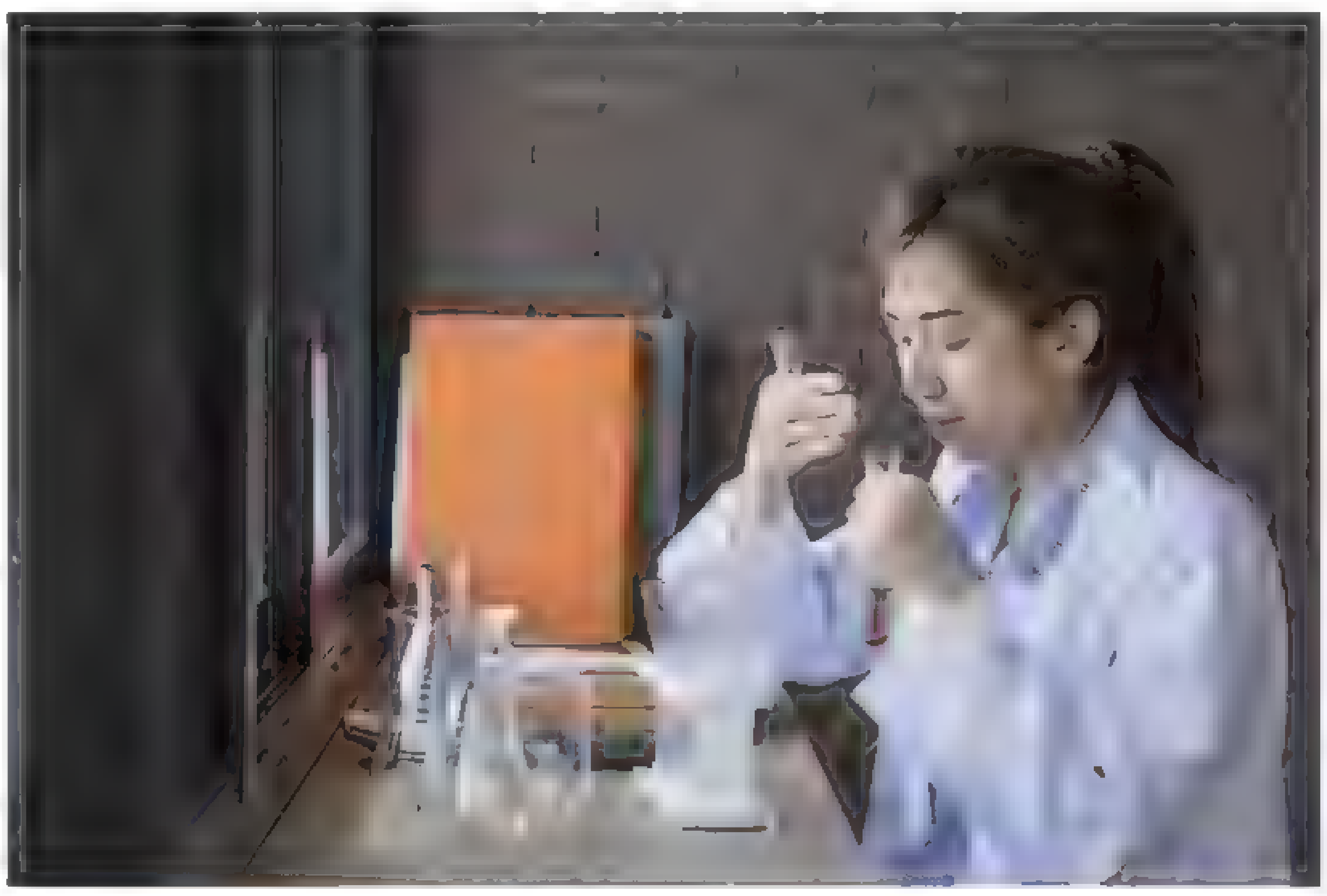


figure 2 The safe way to smell what's in a bottle.

TELLING SUBSTANCES APART

The characteristics that let you recognize a substance are called its **properties**. You can use them to tell substances apart. Examples of the properties of substances are:

- the smell of alcohol is different from the smell of petrol;
- the colour: copper is reddish-orange, gold is yellowish, lead is grey;
- the taste: sugar tastes sweet, table salt tastes salty;
- **flammability**: petrol is flammable but water is not.

SUBSTANCES AND SAFETY

Some substances that are used in the home can be dangerous. Think of methylated spirits, white spirit, bleach, ammonia and all sorts of medicines. A substance can for example be hazardous if:

- you breathe it in;
- you swallow it;
- you get it on your skin, in your eyes or on your clothes;
- it comes close to a flame;
- it is mixed with certain other substances.

This is why there are warnings and labels on the packaging of hazardous substances. The hazards are also indicated by symbols. These pictograms are also known as **hazard symbols**. Figure 3 shows six hazard symbols and their meanings.

figure 3 Six hazard symbols and their meanings.

symbol	meaning + explanation
	**corrosive** can severely affect materials, the eyes and the skin
	**explosive** can be made to explode by a spark or shock
	**inflammable** can be set alight very easily
	**oxidizing** can make things burn more easily or more intensely
	**toxic** can make you very ill or may even be fatal
	**harmful, irritant** is harmful and can irritate the eyes or skin

Bottles containing hazardous substances often have child-proof lids. These have to be pressed down firmly before you can unscrew them.

Practice the concepts using the *Flash cards*.

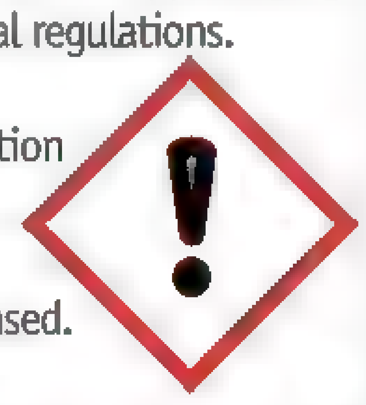
EXTRA H-PHRASES AND P-PHRASES

Figure 4 shows the label on a bottle of drain cleaner. As well as a symbol, the label has several H-phrases and P-phrases. An H-phrase tells you what risk you have to be careful about. The H is for *Hazard* (danger). A P-phrase states the precautions that you should take. The P stands for *Precaution* (how to make sure you are safe).

Drain cleaner is a harmful liquid. It can severely damage your eyes and skin. The H-phrase makes the danger clear, as in "H319: causes severe eye irritation". The P-phrases list suitable precautions, such as in "P280: wear protective gloves, eye protection and protective clothing."

Manufacturers are not allowed to think up their own H-phrases and P-phrases; they must stick to an official list instead. That list, which has applied throughout the European Union since 2015, is the GHS (*Globally Harmonized System of Classification and Labelling of Chemicals*). Before 2015, a system of R-phrases and S-phrases was used. The R stood for *Risk* and the S for *Safety*. You will still find a lot of outdated information on the Internet about this system.

Danger
Hazardous components: sodium hypochlorite. Hazard indications (CLP): H315 – Causes skin irritation | **H319** – Causes severe eye irritation | **H412** – Harmful to aquatic organisms, with long-term consequences. Safety recommendations (CLP): **P102** – Keep out of sight and out of reach of children | **P280** – Wear protective gloves, eye protection and protective clothing. | **P302+P352** – ON CONTACT WITH THE SKIN: rinse with plenty of soap and water | **P305+P351+P338** – IF IN EYES: rinse cautiously with water for several minutes. Remove contact lenses if present and easy to do. Continue rinsing. | **P332+P313** In cases of skin irritation: consult a doctor, **P337+P313** In cases of persistent eye irritation: consult a doctor. **P501** – dispose of the contents/packaging in accordance with local regulations. EUH**206** – Caution! Do not use in combination with other products. Hazardous gases (chlorine) may be released.



Ingredients	%
Anionogenic surfactants	<5%
Sodium hypochlorite	<5%

figure 4 The safety information on the label of a drain cleaner.

COURSE MATERIAL

1 In physics and chemistry, we often talk about the 'properties of a substance'.
- **a** What is meant by a 'property' of a substance?
- **b** Give four examples of substance properties.

2 List one or two distinctive properties of each of the following substance.
- **a** copper *flammability / smell / colour / taste*
- **b** petrol *flammability / smell / colour / taste*
- **c** sugar *flammability / smell / colour / taste*
- **d** alcohol *flammability / smell / colour / taste*

3

Three substances are on a desk in a laboratory:

- a corrosive substance;
- a flammable substance;
- an oxidizing substance.

a Explain why each of these substances is hazardous.

b Write down which symbol from figure 3 belongs with which substance.

A corrosive substance ○ | ○ 1 

B flammable substance ○ | ○ 2 

C oxidizing substance ○ | ○ 3 

D toxic substance ○ | ○ 4 

E harmful or irritant substance ○ | ○ 5 

F explosive substance ○ | ○ 6 

IN PRACTICE

4

Write down a distinctive property of:

a vinegar.

b lead.

c olive oil.

d methylated spirits.

5

Carl has a bottle of mineral water, a bottle of alcohol and a bottle of white spirits in his shed. The labels on the bottles are so old that they are illegible. The three bottles look identical too.

a How can he find out which substance is in which bottle?

b What property of these substances can he therefore use to tell them apart?

6

The same substance can occur in forms that look very different.

a What can sugar look like? Think of how sugar is sold.

b What can water look like (for example in various weather conditions)?

★ 7

When you are working with hazardous substances, the rule is that 'prevention is better than cure'. Car drivers who are smoking should therefore put their cigarettes out before filling up with petrol.
Write down a suitable safety precaution (think one up yourself) for someone who is:

a unblocking a blocked drain with drain cleaner (which is corrosive).
b cleaning a door before painting it, using a very dilute ammonia solution (irritating to the eyes, the skin and the mucous membranes of the mouth and lungs).
c getting grease stains out of their trousers with white spirit (which is flammable).

Test what you know with *Test yourself*.

EXTRA H-PHRASES AND P-PHRASES

8

The label of a bottle of methylated spirits has six phrases on it:

A Flammable liquid and vapour.
B Keep container tightly closed.
C Keep away from heat, sparks, naked flames, hot surfaces and other sources of ignition. – Do not smoke.
D Harmful when swallowed.
E Keep out of sight and out of reach of children.
F IF SWALLOWED: call a poison centre or doctor immediately.

a Say whether each phrase is an H-phrase or a P-phrase.
b Which phrases give precautions for preventing accidents?

- ☐ A
- ☐ B
- ☐ C
- ☐ D
- ☐ E
- ☐ F

c Which phrase tells you what to do if something does go wrong?

- ○ A
- ○ B
- ○ C
- ○ D
- ○ E
- ○ F

9

Find and write down a P-phrase that you might come across:

a on the packaging of a corrosive substance.
b on the packaging of a toxic substance.
c on the packaging of a flammable substance.
d on the packaging of an oxidizing substance.

2 Pure substances and mixtures

LEARNING OBJECTIVES

2.2.1 You can state the differences between pure substances and mixtures.
2.2.2 You can explain what a molecule is and explain what kinds of molecules make up pure substances and mixtures.
2.2.3 You can tell solutions from suspensions.
2.2.4 You can describe how you can separate substances by extraction or filtration.
EXTRA 2.2.5 You can explain how alcohol works as a solvent.

TAXONOMY	LEARNING OBJECTIVES AND EXERCISES				
	2.2.1	2.2.2	2.2.3	2.2.4	2.2.5
Remembering	3ef	1, 2ab	3bcd	3a, 4abcde	10a
Understanding			5abcd, 6abc	7abcd	
Using			9a	8a, 9b	10bcd, 11a
Analysing				8b	11bcd

Water from the tap contains a lot more substances than just water. The taste of the water changes as substances combine. That's why you can choose between various brands of mineral water in the supermarket that all taste a tiny bit different.

MIXTURES AND PURE SUBSTANCES

Figure 1 shows the ingredients on the label of a bottle of ice tea. Water is the most important ingredient – as in any soft drink – and so it is listed first. The ice tea also contains sweeteners, acids, aromas and flavourings. There is also a preservative in it. All these substances are stated separately on the label.

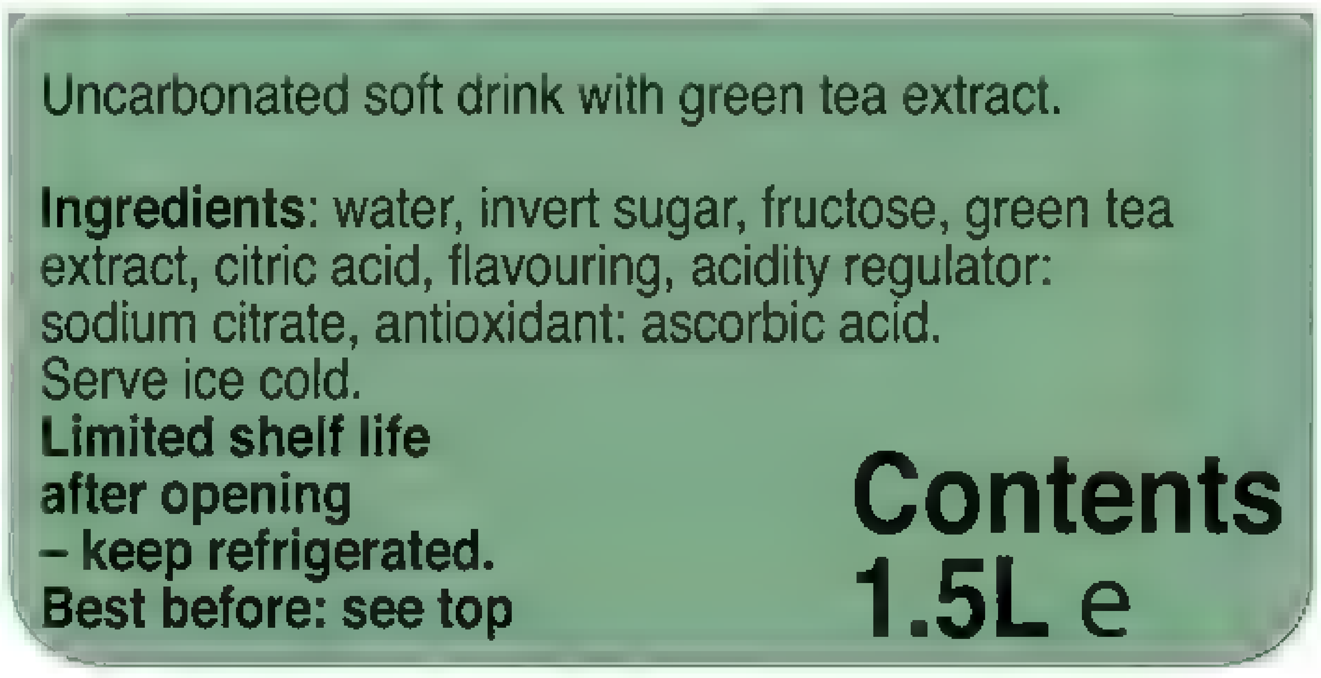


figure 1 The ingredients of ice tea.

Most of the substances that you will find at home are **mixtures.** You'll see that straight away if you look at the packaging of a foodstuff or a medicine. It states the various substances that are in the product: the ingredients. Sometimes the ingredients themselves are mixtures too.

Substances that are not mixtures are called **pure substances.** One example of a pure substance is granulated sugar. A bag of sugar contains only sugar – there are no other substances mixed in with it. Table salt that has not been iodized is also a pure substance.

After a lot of experimenting, physicists concluded that substances are made up of extremely small particles. These particles are called **molecules.** A pure substance (a pure chemical compound) consists of just a single type of molecule: pure water contains only water molecules, pure sugar contains only sugar molecules and pure alcohol contains only alcohol molecules. A mixture contains different kinds of molecules.

SOLUTIONS

If you put sugar in a glass of hot water and stir it for a while, you will see that the sugar granules disappear. We say that the sugar has dissolved in the water. The mixture that you get is known as a solution. Water is the solvent in this case and sugar is the dissolved substance or 'solute'. You can tell that the sugar hasn't actually disappeared if you taste the water, though: it now tastes sweet.

When a solid substance like sugar is dissolved, the molecules of the substance are scattered around between the molecules of the solvent. Figure 2 shows you what is happening. After a while, the solid substance is completely dissolved. The molecules of the dissolved substance are then surrounded on all sides by molecules of the solvent.

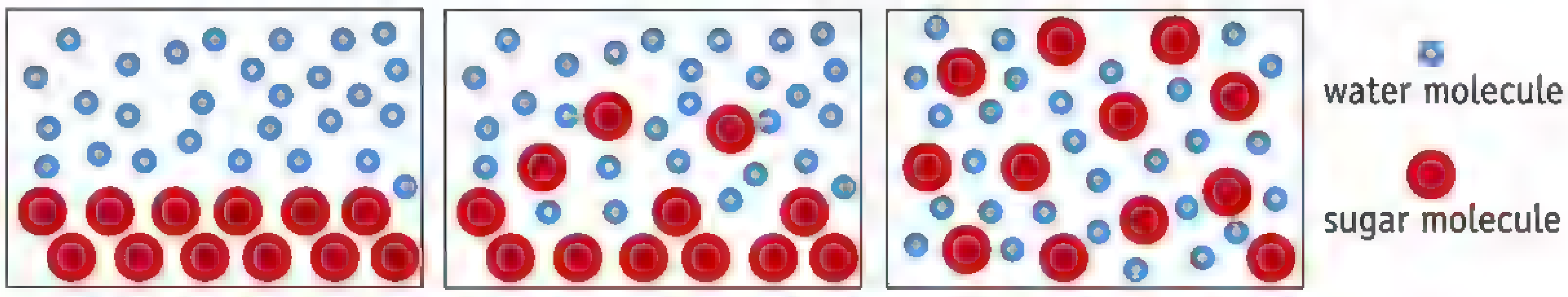


figure 2 When sugar dissolves, the sugar molecules become distributed among the water molecules.

Many of the substances that you can find at home are solutions. Examples are tea, energy drinks and soft drinks, deodorant and perfumes.

RECOGNIZING SOLUTIONS AND SUSPENSIONS

Solutions are clear and always stay perfectly mixed. A coke is a good example: the soft drink does not change if you leave it in the cupboard. After a year, it is still just as thoroughly mixed as the day that you bought it. If a mixture is cloudy (opaque) and separates out over the course of time, then it cannot be a solution.

Paint, for instance, is not a solution. Instead, it is a suspension: a liquid in which a very fine powder is floating. Because paint separates out – the powder will settle at the bottom of the tin over time – you have to stir paint before using it. If you see 'shake well before use' or 'stir before use' on a substance's packaging, then it is probably a suspension.

A bottle of mineral water may say that it contains 'pure mineral water'. In chemical terms, though, mineral water is not a pure substance. There are all kinds of substances dissolved in the water, as you can see on the label. The word 'pure' in this case just means that the water is not contaminated with harmful substances or bacteria. You can drink it with no risk to your health.

THE SIZE OF A MOLECULE

Molecules are incredibly small. Their dimensions are therefore measured in nanometres. One nanometre is a billionth of a metre: 1 nm = 0.000000001 m. The diameter of a water molecule is about 0.15 nm. A sugar molecule is a bit bigger, with a diameter of 1 nm.

The following example gives you an idea of just how small a single water molecule is. Suppose you could blow up a ping-pong ball to the size of the Earth. If you could 'blow up' a water molecule by the same amount, it would then be the size of the table tennis ball. The Earth is about 300 million times the size of a ping-pong ball, which is in turn about 300 million times bigger than a water molecule (see figure 3).

figure 3 The steps in size from a water molecule to a table tennis ball and from a table tennis ball to the Earth are the same.

Because molecules are so small, they can fit through very small gaps. You can see that if you pour a solution through a coffee filter. Nothing remains in the filter. Molecules can pass through the filter by going through small gaps between the paper fibres. Even though the gaps are too small for the human eye to see, they are huge holes compared to the molecules.

EXTRACTING AND FILTERING MIXTURES

If you add hot water to ground coffee (figure 4), the aroma, colour and flavour components in the coffee dissolve in the water. In other words, you are using the hot water to get the aromas, colorants and flavourings out of the coffee. This is known as **extraction** (literally 'pulling out'). You are extracting the aroma, colour and flavour substances using hot water as the solvent.

You use a filter to remove the coffee grounds. The coffee can flow through the holes in the filter easily. The coffee grounds can't because the granules are much too big for the holes in the filter. The coffee therefore ends up in the coffee pot and the grounds remain behind in the filter. This is called **filtration** (in other words, passing through a filter). The coffee is referred to as the **filtrate** and the coffee grounds are the **residue**.

figure 4 Filtering coffee.

Practice the concepts using the *Flash cards*.

EXTRA ALCOHOL AS A SOLVENT

Some substances such as fats and oils do not dissolve in water. For these substances, you need a different solvent such as alcohol or white spirit. You can use alcohol for degreasing things, for example. The grease on the object dissolves in the alcohol and you can then wipe the alcohol off with a cloth.

Alcohol is used as a solvent in all sorts of products (see figure 5). Examples are perfumes, deodorants and certain types of ink and paint. Some pens have 'alcohol-based' ink. When you write or draw with the pen, the alcohol evaporates and the dyestuffs remain. You can then smell the alcohol clearly.

figure 5 Many perfumes consist of aromatic substances that are dissolved in alcohol.

The substance that is generally called 'alcohol' is known in chemistry as ethanol. If a label mentions ethanol, it means 'ordinary' alcohol, the same substance as is in beer and wine. Chemists use the word alcohol as a collective name for a whole group of compounds. To them, ethanol is one of the many different alcohols.

COURSE MATERIAL

1 What is a molecule?

2 What is the chemical term for a substance:

a that is made up of different sorts of molecules?

b that is made up of only one kind of molecule?

3 Are the following statements true or false?

a When you make coffee, you are using water as a solvent. *true / false*

b Solutions are always colourless (just like water). *true / false*

c A suspension does not remain perfectly mixed over the course of time. *true / false*

d A suspension is clear: you can see through it. *true / false*

e Suspensions and solutions are not pure substances. *true / false*

f Most substances in daily life are mixtures. *true / false*

4 Insert the correct words into the text.

a Ground coffee beans contain a lot of different aromas and ....

b These substances dissolve when you pour .... over the ground coffee.

c The substances that do not dissolve in water remain in the ....

d The freshly made coffee in the coffee pot is called the ....

e The coffee grounds left in the filter are called the ....

IN PRACTICE

5 Say whether you think each of these liquids is a solution or a suspension and why.

a Tea with sugar (and no milk) is a *solution / suspension* because it is *cloudy / clear*. The liquid *stays / does not stay* thoroughly mixed.

b Orange juice is a *solution / suspension*. The liquid *stays / does not stay* thoroughly mixed because the bits of fruit pulp *sink / do not sink* to the bottom.

c An energy drink is a *solution / suspension* because it is *cloudy / clear*.

d Yoghurt is a *solution / suspension* because it is *cloudy / clear*.

6 Charlotte puts a spatula-tip of white powder into a test tube. She adds distilled water and shakes it. Figure 6 shows you what the contents of the test tube look like, just after shaking it (left) and one hour later (right).

a How can you tell that the white powder was not dissolved?

b What kind of mixture was obtained by shaking?
a *solution / suspension*

c What happened to the white powder after an hour?

figure 6 Charlotte's experiment.

7 A tea bag is a quick way of making a cup of tea (figure 7).
In this situation, what is:

a the solvent?

b the filter?

c the filtrate?

d the residue?

figure 7 Making tea = extraction and filtering.

8 Filters often get clogged up and the liquid can then no longer flow through them.

a Give an explanation for this.

b Will a filter get clogged up more easily by a coarse powder or a fine powder? Explain your answer.

★ 9 Sometimes you can separate the substances in a mixture by filtering the mixture.

a Explain why this does work for a suspension and doesn't work for a solution.

b The holes in paper filters have diameters of 10 to 25 micrometres.
1 micrometre = one millionth of a metre = 0.000001 m.
Suppose someone was making a model of water molecules in a filter. In their model, the water molecules are the size of ping-pong balls.
How big will the gaps in the filter be if they are represented at the same scale? Show your calculations.

Test what you know with *Test yourself*.

EXTRA ALCOHOL AS A SOLVENT

10 Ethanol is a component of all sorts of products.

a What is the everyday name for ethanol?

b Why is ethanol used as a solvent in perfumes?

c A site with household tips says "You can remove greasy stains from fabrics by dabbing them with spirits such as vodka."
Explain why the stains disappear when dabbed with vodka, but not if pure water is used.

d Glands in your skin produce greases that protect the skin against drying out.
Explain why your skin can feel dry if it comes into contact with ethanol a lot.

11 A perfume is a mixture of various aromatic substances in a solvent. In most perfumes, that solvent is alcohol.

a As long ago as Roman times, people pressed flowers to get aromatic substances that could be used in ointments, oils and other products. In the Middle Ages, the Arabs discovered that alcohol improved the shelf life of these aromas considerably.
Why was this discovery important?

b Between 20% and 30% of a perfume consists of aroma substances, dissolved in alcohol. Aromatic substances make up 5% to 10% of an eau de toilette and 2% to 3% of an eau de cologne.
Explain why a perfume is more expensive than an eau de cologne.

c Explain what happens to the ingredients of a perfume when you put perfume on.

d You are going to try out a new perfume in the shop and you want to know whether it smells nice.
Why is it better not to smell the perfume straight after putting it on?

3 Mass and volume

LEARNING OBJECTIVES

2.3.1 You can determine the mass of a quantity of a substance.
2.3.2 You can explain the difference between mass and volume.
2.3.3 You can determine the volume of a quantity of liquid.
2.3.4 You can calculate the volume of a rectangular object.
2.3.5 You can determine the volume of an irregularly shaped object
EXTRA 2.3.6. You can calculate the concentration and percentage by volume of dissolved substances in mixtures.

TAXONOMY	LEARNING OBJECTIVES AND EXERCISES					
	2.3.1	2.3.2	2.3.3	2.3.4	2.3.5	2.3.6
Remembering	2ab, 3a		1b, 2cdef	1c	1d	15a
Understanding	3, 4abcdefghij		5b, 9abcdefghij		11	
Using	13		5a	8, 14ab	10	15b, 16abc
Analysing		6	7		12	

You often need a specific quantity of a substance – no more, and no less. Recipes, for instance, often say how much of each ingredient you need to use (figure 1). And it is extremely important that medicines contain the correct amount of the active ingredient.

MEASURING OUT A QUANTITY OF A SUBSTANCE

There are various ways of measuring out substances. You will have noticed this when you work in the kitchen. Scales are useful for solid substances such as flour and sugar. Liquids such as water and milk are often measured out in a measuring jug. Similar measuring instruments are used in physics and chemistry.

MASS

Scales let you determine the mass of a quantity of a substance (figure 2). The mass is a measure of the quantity of the substance: twice as much mass means that you have twice the amount of the substance, and so forth. If you double the mass when weighing out sugar, the number of sugar molecules will be doubled as well.

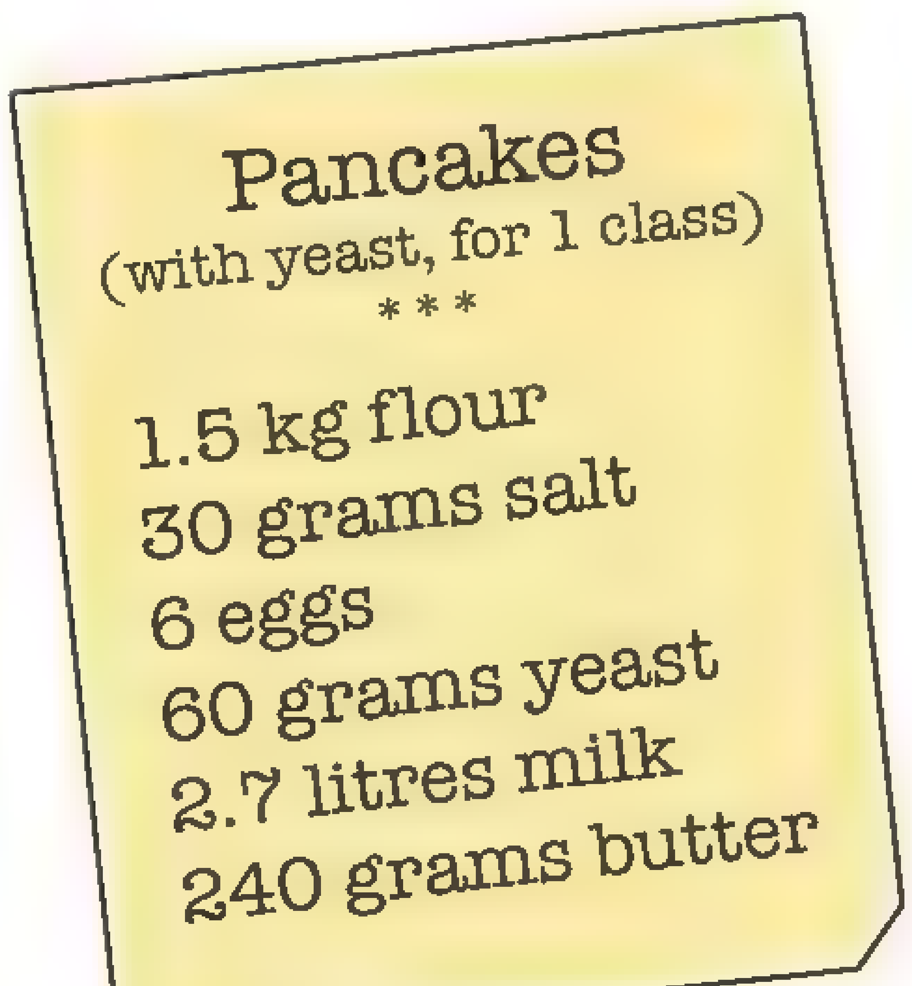


figure 1 The ingredients for quite a stack of pancakes.

figure 2 Working with scales.

The unit of mass is the kilogram (kg). Various larger and smaller units are derived from the kilogram, such as the ton (t), the gram (g) and the milligram (mg). Remember:

- 1 t = 1000 kg
- 1 kg = 1000 g
- 1 g = 1000 mg

Mass and weight are two different things in physics. The mass says how much substance there is in an object. The weight is the force that the object exerts on your hands (if you lift it up) or on the floor (when you put it down). How much the object weighs depends not only on its mass (i.e. the amount of substance in it) but also on the strength of gravity.

In everyday life, you don't see any difference between mass and weight because gravity is equally strong everywhere on Earth. But that's no longer true if you leave the Earth. Astronauts are well aware that their weight can vary enormously, whereas their mass – the amount of substance making up their bodies – stays the same. Objects weigh less on the Moon than they do on Earth.

VOLUME

A measuring cylinder lets you determine the **volume** of a quantity of liquid. You then know how much space the liquid takes up. The volume is a measure of the quantity of a substance: 2× as much volume means that you have 2× as much of the substance, and so forth. Figure 3 shows you how to read a measuring cylinder: with your eyes at the same level as the surface of the liquid. This lets you find the volume of the liquid in millilitres (mL).

The millilitre (mL) is a derived unit based on the litre (L). The litre is only used for liquids and gases. In other cases, you use the cubic decimetre (dm^3). However, the litre and the dm^3 mean exactly the same thing:

- 1 litre is the same as 1 dm^3: the space occupied by a cube with sides of 1 dm;
- 1 millilitre is the same as 1 cm^3: the space occupied by a cube with sides of 1 cm (figure 4).

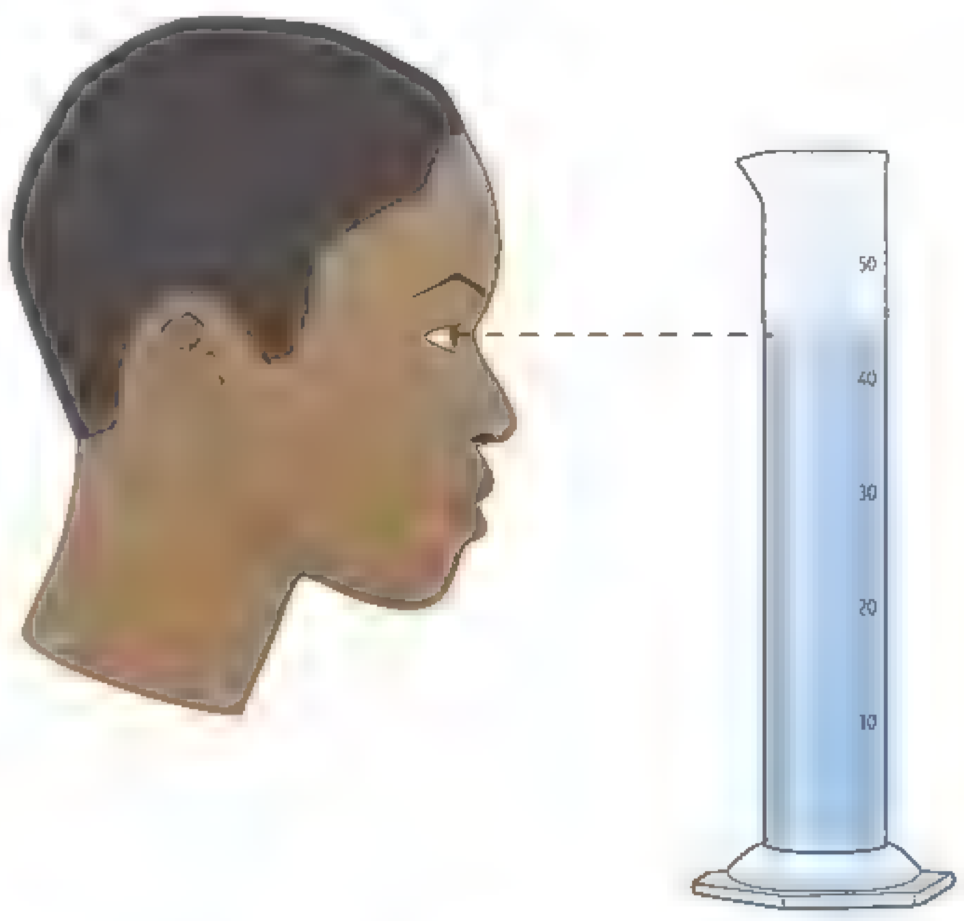


figure 3 How to read a measuring cylinder.

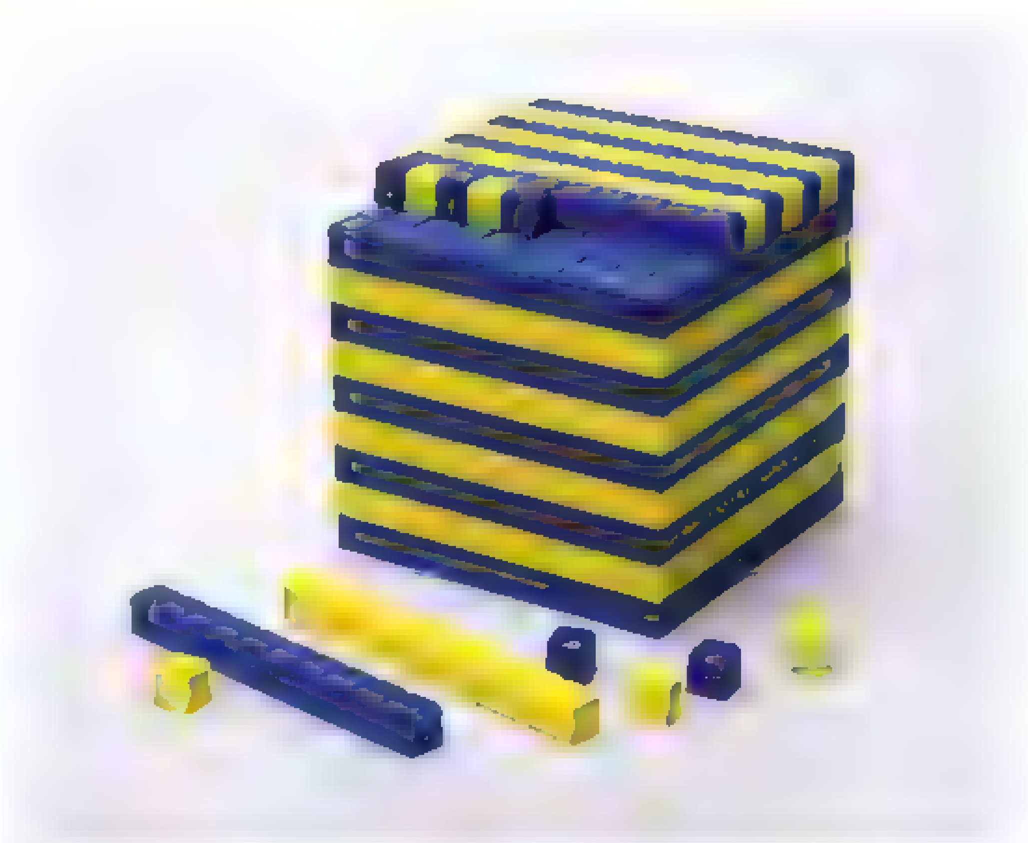


figure 4 1 dm^3 = 1000 cm^3.

Remember:

- 1 m^3 = 1000 dm^3 = 1000 L
- 1 dm^3 = 1000 cm^3 = 1 L
- 1 cm^3 = 1 mL

CALCULATING THE VOLUME

Objects take up a specific amount of space. That space is referred to as the volume of the object. You can calculate the volume of a rectangular object using the following formula (figure 5):

volume = length × width × height

Or in symbols:

$$V = l \cdot w \cdot h$$

where:

- V is the volume in cubic centimetres (cm^3);
- l is the length in centimetres (cm);
- w is the width in centimetres (cm);
- h is the height in centimetres (cm).

You can calculate the volume of a cylinder using the following formula (figure 6):

volume = pi × (radius)^2 × height

Or in symbols:

$$V = \pi \cdot r^2 \cdot h$$

where:

- V is the volume in cubic centimetres (cm^3);
- r is the radius in centimetres (cm);
- h is the height in centimetres (cm).

The radius is half the diameter.

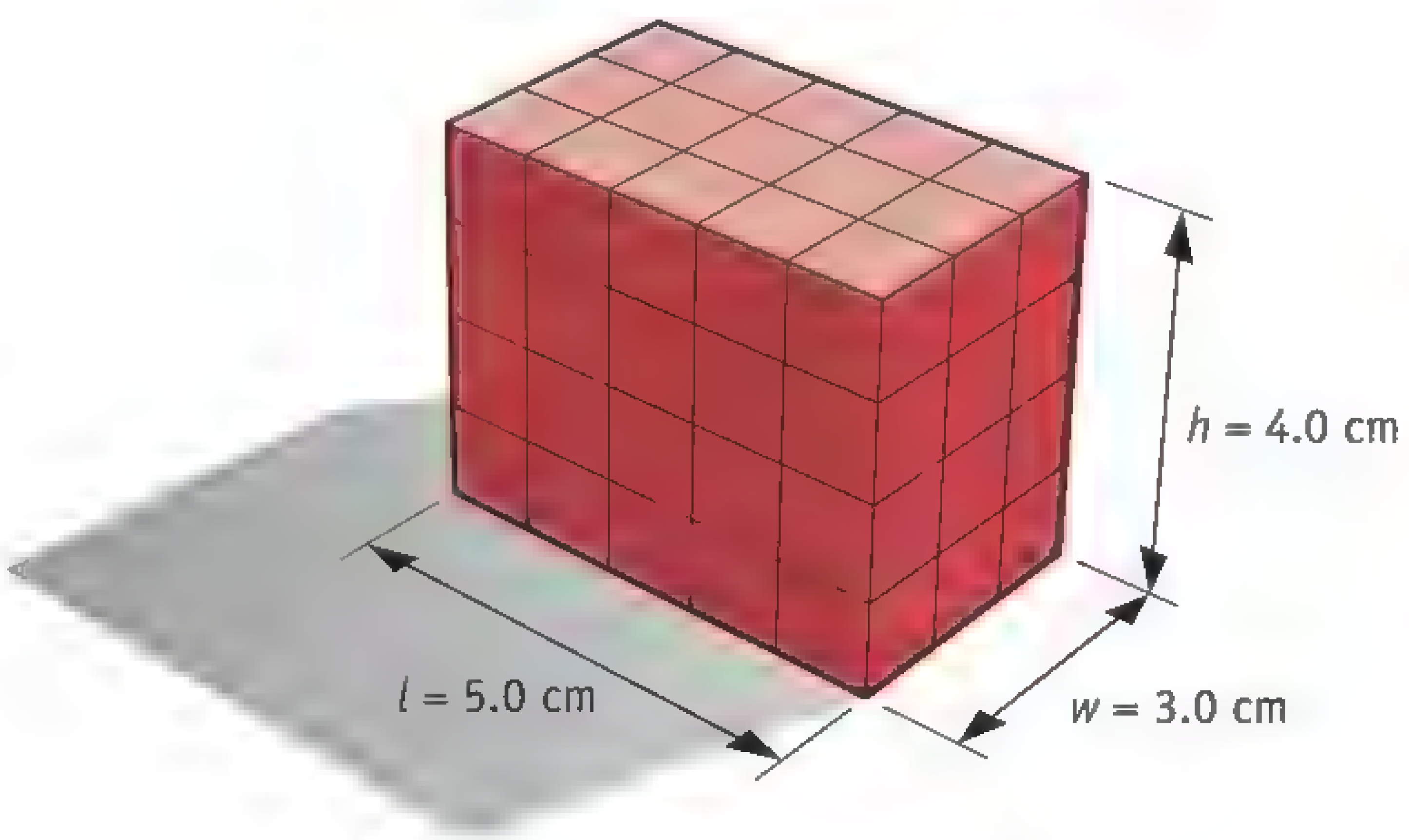


figure 5 The volume of a rectangular object: $V = l \cdot w \cdot h$.

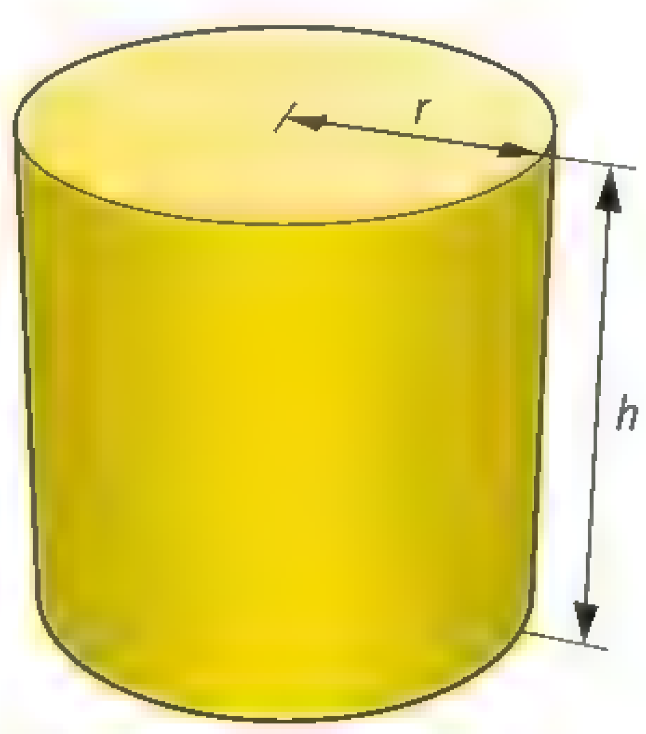


figure 6 The volume of a cylinder: $V = \pi \cdot r^2 \cdot h$.

EXAMPLE EXERCISE 1

Calculate the volume of a roll of biscuits. The roll is 20 cm long and has a diameter of 11.2 cm. Round the answer off to a whole number.

given $r = \frac{11.2}{2} = 5.6$ cm
$h = 20$ cm

required $V = ?$

working $V = \pi \cdot r^2 \cdot h$
$= \pi \times (5.6)^2 \times 20$
$= 1970$ cm^3

DETERMINING THE VOLUME EXPERIMENTALLY

EXP. 5

The volume of an irregularly shaped object such as a pebble can be determined by the **immersion method** (figure 7). It works like this:

1. Fill a measuring cylinder with water to a given level.
2. Read the level of the water.
   This is called the starting level.
3. Lower the object carefully into the water.
   The object must be completely submerged.
4. Read the level of the water again.
   This is called the final level.
5. Calculate the final level minus the starting level.
   This is the volume of the object.

An overflow vessel makes it even easier (figure 8). You have to fill the overflow vessel with water right up to the overflow spout. When you submerge the object in it, the quantity of displaced water that will flow out through the spout has the same volume as the object. If you use a measuring cylinder to catch the water that flows out, you can determine the volume.

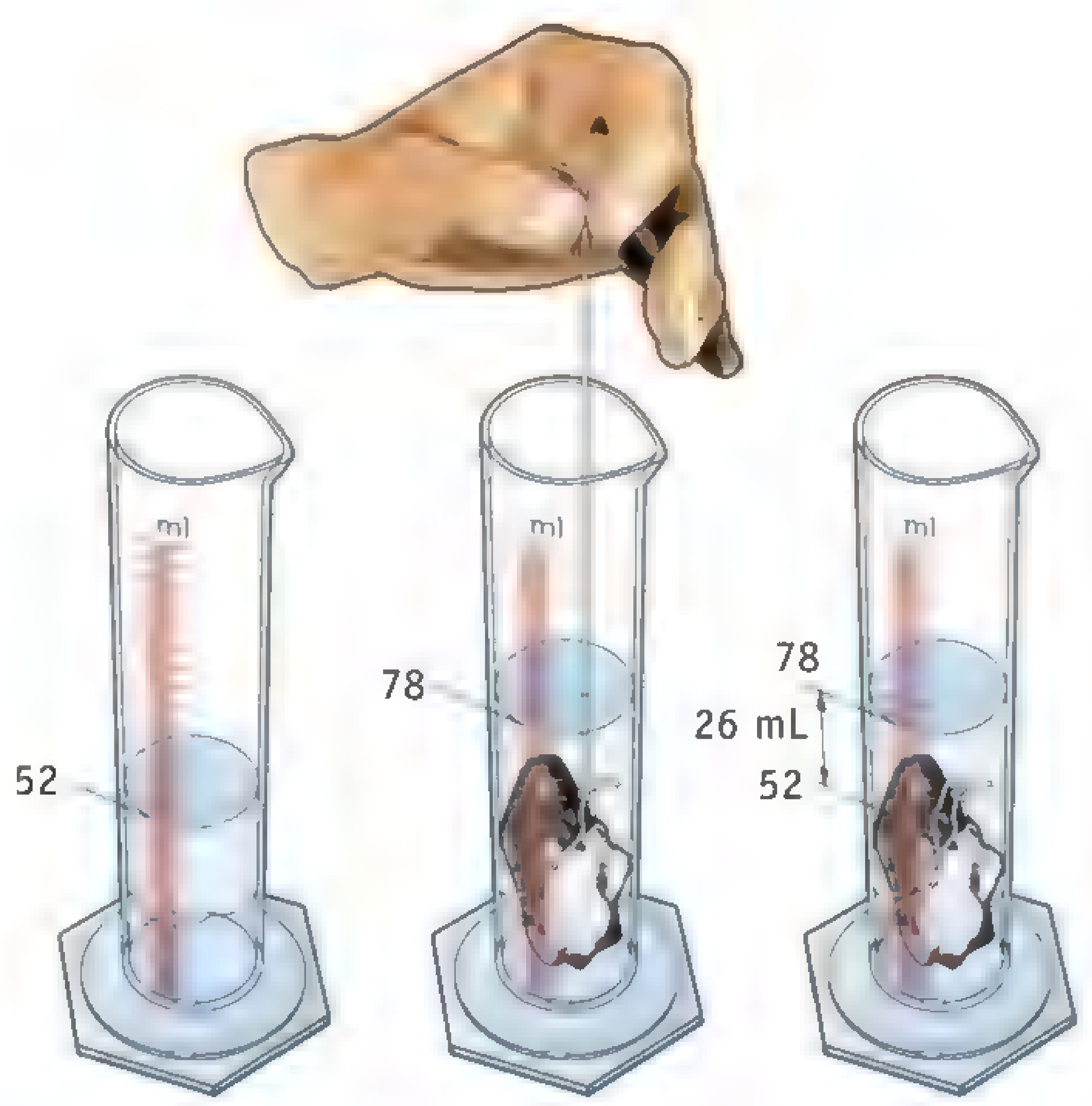


figure 7 This is how the immersion method works.

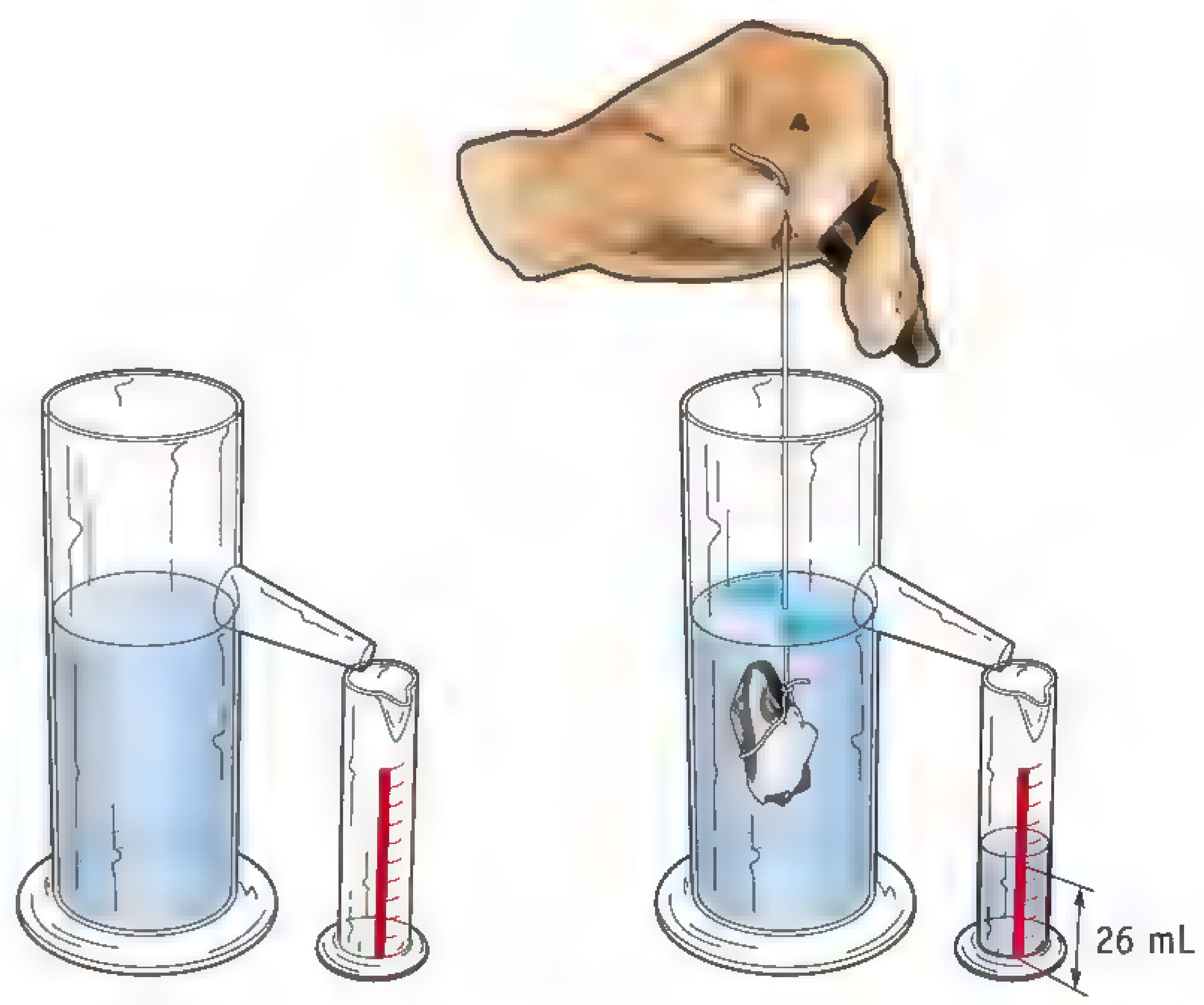


figure 8 The immersion method using an overflow vessel.

Practice the concepts using the *Flash cards*.

EXTRA CARATS

The mass of a gemstone or pearl is not given in grams. An old unit called the carat is used instead. The word 'carat' comes from the Greek word *keratia*, the seed of the carob tree. Its seeds always have the same mass and so people in the past used to express the weight of a gemstone as a number of carob seeds, or carats (figure 9). Because exactly the same seeds weren't used everywhere, the Dutch carat was a little bit heavier than the Italian carat. The carat is now defined as being 200 milligrams. So a pearl of 20 carats has a mass of 20 × 200 = 4000 mg = 4 g.

figure 9 The *Golden Jubilee* is the world's biggest cut diamond at almost 546 carats.

Gemstones are very expensive, so a small difference in mass can mean a big difference in price. It is also why fractions of carats are used, such as an eighth (1/8) or sixteenth (1/16) of a carat. For even greater accuracy, 'points' are used. 1 carat can be divided into 100 points. So a diamond with a mass of 2.36 carats is 2 carats and 36 points.

COURSE MATERIAL

1

Explain:

a how you can measure the mass of a quantity of a solid substance.
b how you can measure the volume of a quantity of a liquid.
c how you can determine the volume of a rectangular block.
d how you can determine the volume of a pebble.

2

Convert.

a 1 kg = ... g
b 1 g = ... mg
c 1 m^3 = ... dm^3
d 1 dm^3 = ... cm^3
e 1 L = ... mL
f 1 mL = ... cm^3

IN PRACTICE

3

Many packages state the mass of the contents in grams or kilograms.
Calculate the missing data and use it to complete table 1.
See the skills section on *Working with prefixes*.

table 1 The contents in grams and kilograms.

The contents of a	have a mass of
bag of sugar	1000 g = ... kg
packet of couscous	500 g = ... kg
bag of noodles	400 g = ... kg
pack of butter	250 g = ... kg
packet of cocoa powder	100 g = ... kg
shaker of pepper	50 g = ... kg

4 Convert.

See the skills section on *Converting units*.

a	250 g	=	kg	**f**	1.3 kg	=	g
b	0.625 kg	=	g	**g**	0.25 t	=	kg
c	0.5 g	=	mg	**h**	0.75 kg	=	g
d	350 mg	=	g	**i**	810 kg	=	t
e	0.035 g	=	mg	**j**	8 mg	=	g

If you need a bit more practice converting mass units, go to the *Skills Trainer* in Section 3 (Mass and volume).

5 Figure 10 shows three measuring cylinders.

a How much liquid is in each of the measuring cylinders? Read the level and write it down.

measuring cylinder 1: .... mL

measuring cylinder 2: .... mL

measuring cylinder 3: .... mL

b You have to measure out 25 mL of water.
Which would be the best measuring cylinder to use and why?

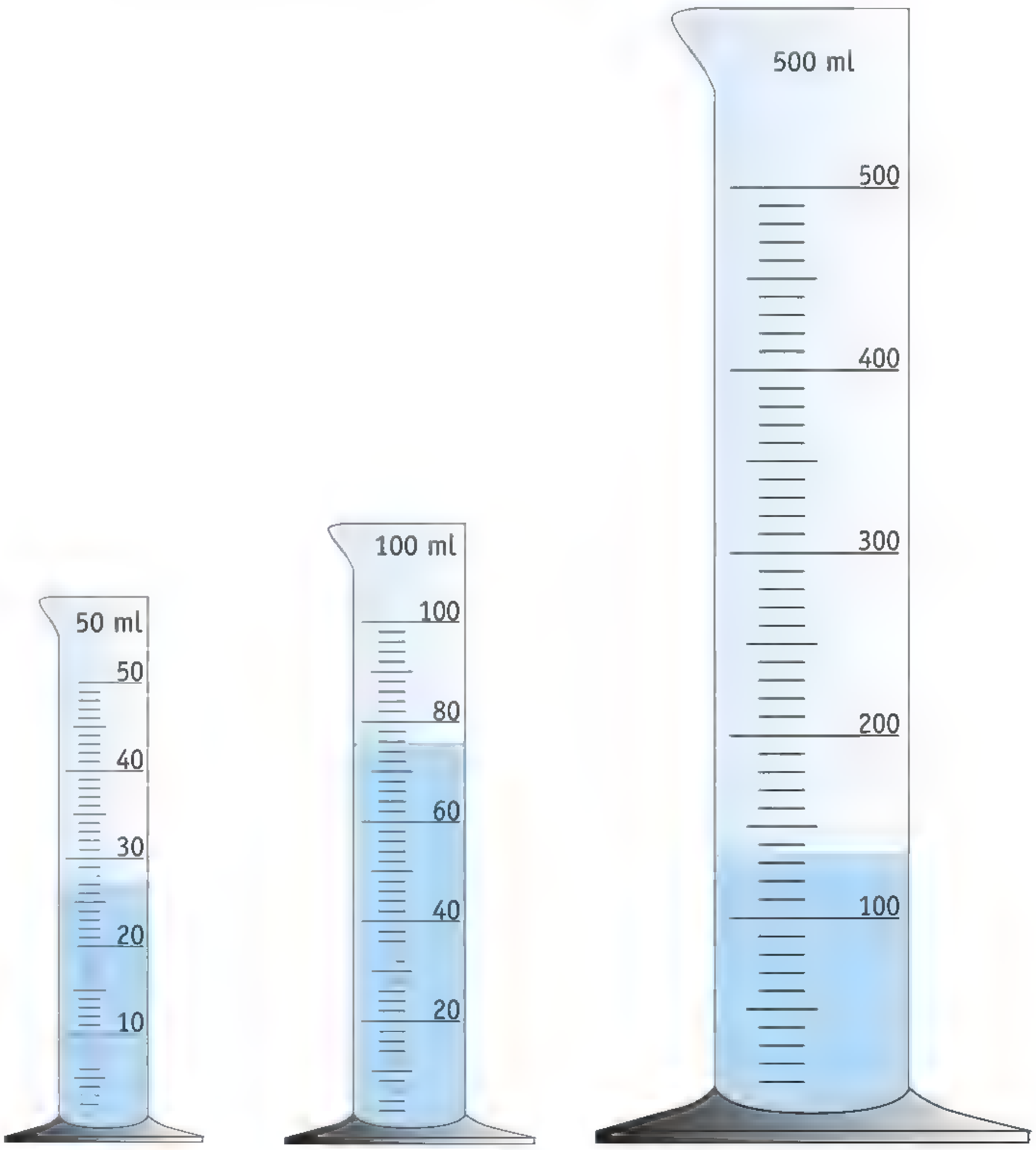


figure 10 Three measuring cylinders.

6 In the International Space Station (ISS), an astronaut weighs almost nothing.
Is the mass of an astronaut in the ISS also almost zero?

7 Around the home, measuring jugs may be used that look like the measuring jugs in figure 11.
In which of the drawings is the graduated scale on the measuring jug drawn correctly?
Explain your choice.

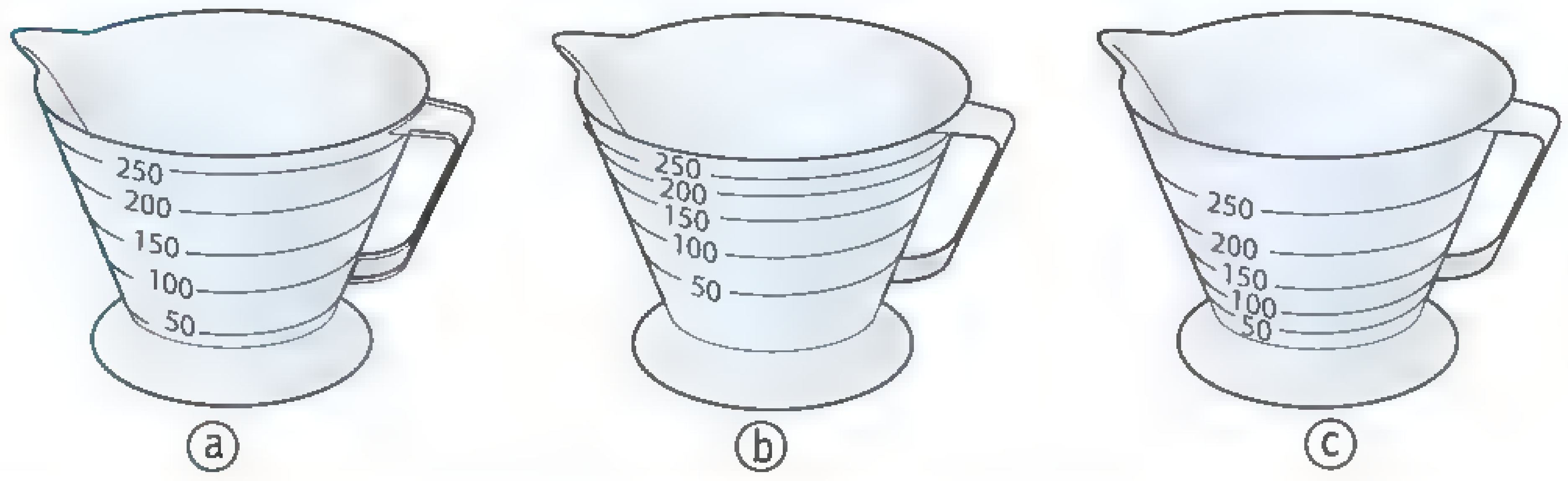


figure 11 Three measuring jugs with different graduated scales.

8 Calculate the volumes of the objects shown in figure 12. Round the answers off to whole numbers. Always show all your calculation steps.

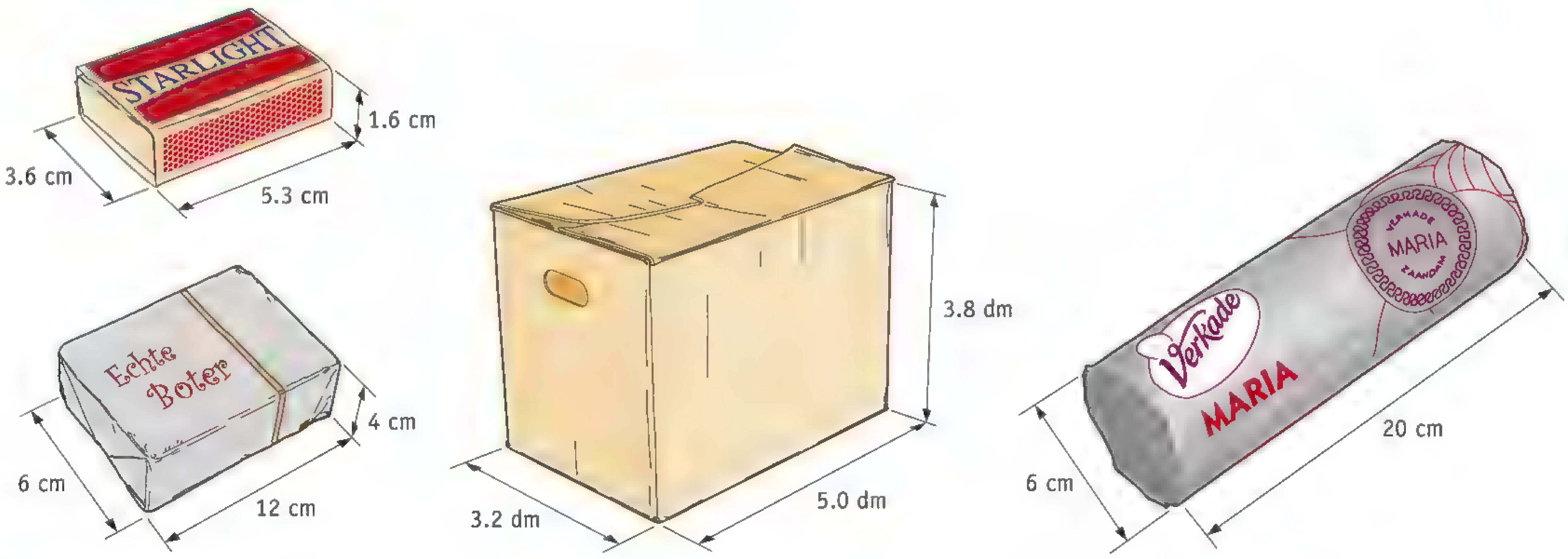


figure 12 Four objects.

9 Convert.

a 0.05 L = ... mL

b 250 mL = ... L

c 750 cm^3 = ... dm^3

d 0.8 dm^3 = ... cm^3

e 10 mL = ... cm^3

f 0.625 m^3 = ... dm^3

g 440 cm^3 = ... dm^3

h 6.5 dm^3 = ... L

i 35 mL = ... L

j 0.5 m^3 = ... L

10 Use the drawings in figure 13 to determine the volume of the pebble. Show all your calculation steps.

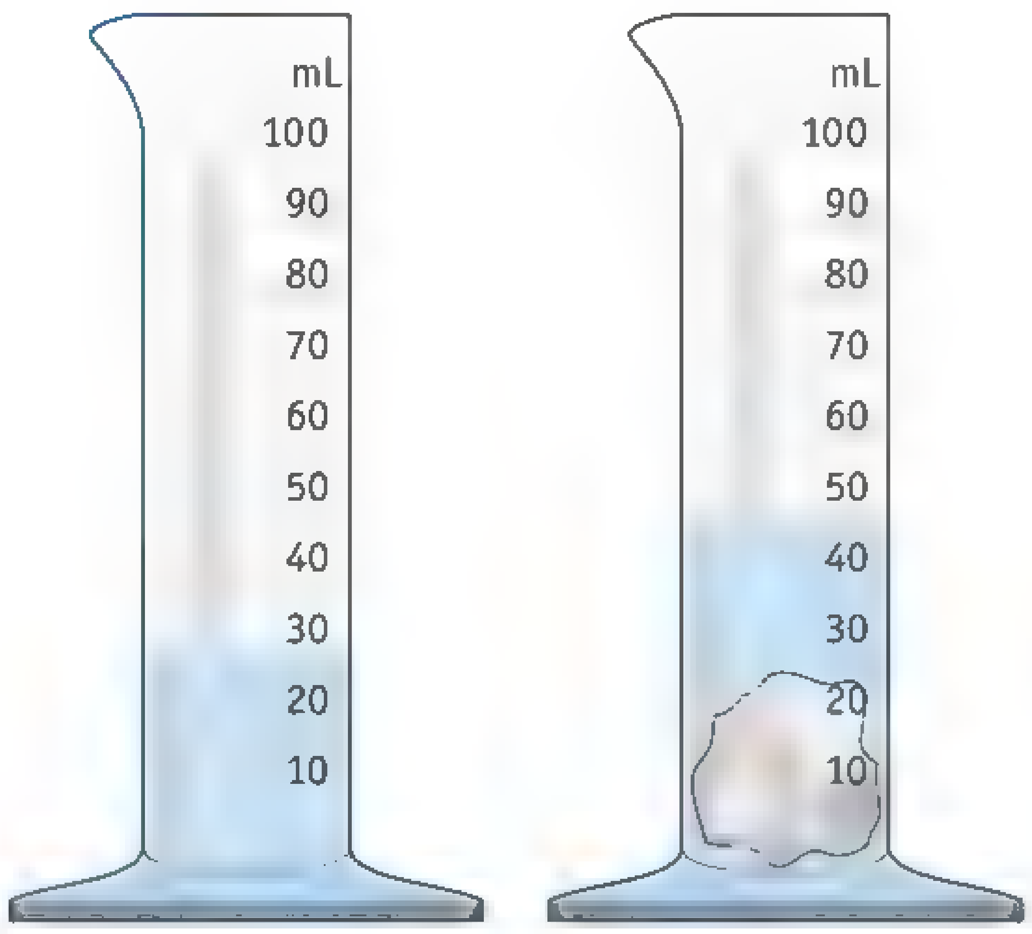


figure 13 What is the volume of the pebble?

11 You could also use the immersion method in reverse: start by determining the final level, then remove the object and determine the starting level.
Explain why this is not such a good method.

12 Wood floats on water.
How could you still use the immersion method to determine the volume of a block of wood? Write down two different ways.

13 A particular painkiller contains 200 mg of its active ingredient per tablet. The information leaflet says that you may not take more than 1.5 g of the active ingredient a day.
Calculate how many tablets you may take each day.

★ 14 The headline above a weather report says, “80 millimetres of rain in two days!”

a How many litres of water fall on a surface with an area of 1 dm^2 if the depth is 80 millimetres?

b Calculate how many litres of water fell on a garden of 6 by 20 m in that period. Show all your calculation steps.

Test what you know with *Test yourself*.

EXTRA CARATS

15 Answer the following questions.

a What does a 'carat' mean?

b Calculate the mass in grams of a diamond of $2\frac{1}{16}$ carats.

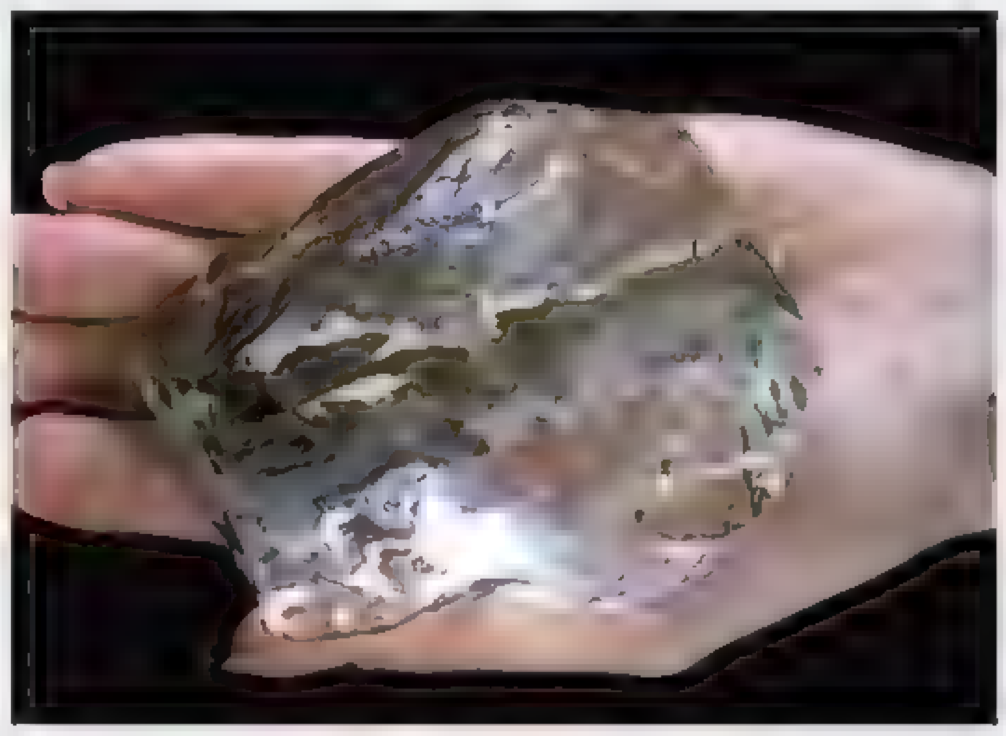
★ 16 The Cullinan is the biggest uncut diamond that has ever been found. When it was found in a mine in South Africa in 1905, it was weighed to be 621.35 g.

a How many carats was the Cullinan then? Show your calculation too.

b Read figure 14.
Calculate the mass of the *Great Star of Africa*.

c In the end, the losses while cutting the diamonds came to 5%.
Calculate how many carats of cut diamonds were produced in total from the Cullinan.

The Cullinan



figuur 14 Replica of the Cullinan.

The Cullinan was cleaved and cut successfully in Amsterdam by Joseph Asscher of the company of the same name, the leading diamond cutter of the time. A small "window" was cut into the surface of the stone so that Asscher could see the cleavage lines and inclusions (the imperfections). He walked around for days with the stone in his pocket, studying it time and time again. On 10 February 1908, he took the plunge. He had made a small cut in the stone and was going to cleave it there, with the risk that it could shatter. The blow that he gave the stone to cleave it took so much out of him that he fainted afterwards. Nevertheless, it all went flawlessly.

Nine large diamonds and 96 smaller ones were cut from the Cullinan. The biggest is called the *Great Star of Africa*; it is 530.4 carats and is now in the Royal Sceptre in the British Crown Jewels.

Uit: *Wikipedia*.

4 Density

LEARNING OBJECTIVES

2.4.1 You can explain what the density of a substance is.
2.4.2 You can explain that the density of a substance is one of its properties.
2.4.3 You can calculate the density of a substance if the mass and volume are given.
2.4.4 You can use the density of substances to explain why they sink or float in water (or air).
EXTRA 2.4.5 You can use the density of substances to explain when a gas will rise.

TAXONOMY	LEARNING OBJECTIVES AND EXERCISES							
	2.4.1	2.4.2	2.4.3	2.4.4	2.4.5	2.3.1*	2.3.3*	2.3.5*
Remembering	1, 2ab		2cd					
Understanding		3abc, 4b, 5b, 6bc		8b	11			
Using			4a, 5a, 6a, 10d	8a	12b, 13b	10b		10a
Analysing			7ab, 9	8cd	12a, 13a		10c	

* You can find this learning objective in an earlier section.

People often say that one substance is heavier or lighter than another. If you ask someone "Why are alloy wheels often made of aluminium?" the reply is something like, "Because aluminium is a very light metal" or "Because aluminium is much lighter than steel".

LIGHT AND HEAVY SUBSTANCES

How can you find out if aluminium is lighter than steel? To do that, you have to be able to compare two substances 'fairly'. You can't just weigh an aluminium object and a steel object: an aluminium bicycle frame could easily be heavier than the steel handlebars.

A fair way of comparing the substances is as follows:
1 Take a 1 cm^3 block of each substance (figure 1).
2 Determine the mass of each block using scales.
3 The block with the lower mass is made of the 'lighter' substance.

An aluminium block of 1 cm^3 has a mass of 2.7 grams. A steel block of 1 cm^3 has a mass of 7.9 grams. Aluminium is therefore about three times lighter than steel.

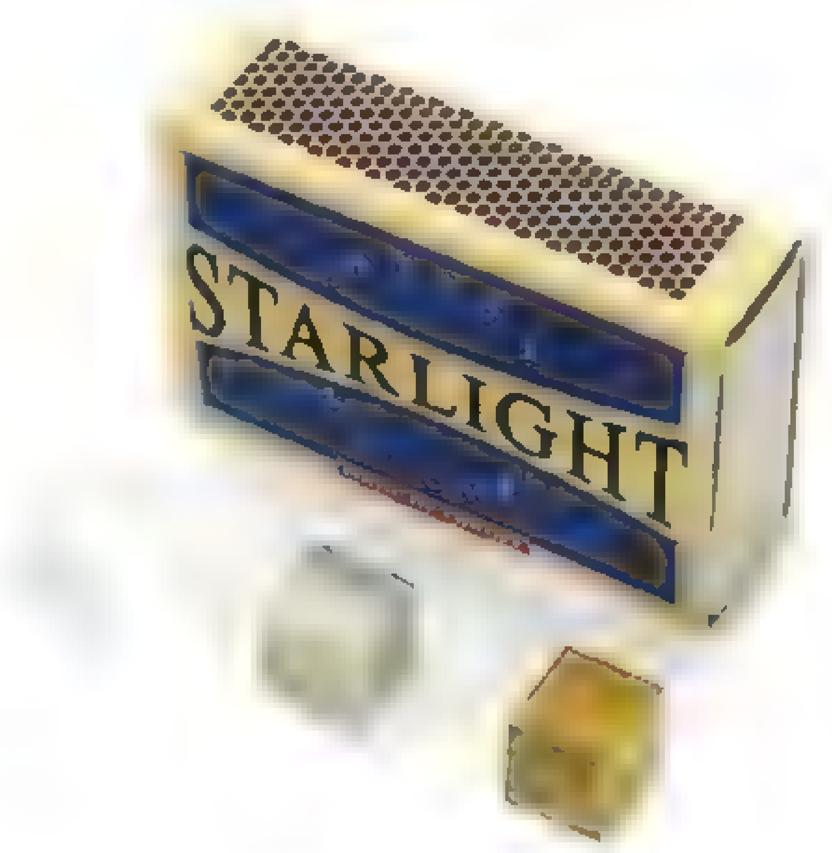


figure 1 Three 1 cm^3 blocks: Perspex (1.2 g), aluminium (2.7 g) and brass (8.5 g).

THE DENSITY OF A SUBSTANCE

A 1 cm³ block of aluminium always has a mass of 2.7 g. That is one of the properties of the substance aluminium: there is always a mass of 2.7 g in a volume of 1 cm³. This property is so important that there is a special word for it, the **density**. You say that the density of aluminium is 2.7 grams per cubic centimetre (g/cm³).

Density is a property of a substance: every substance has its own density. Conversely, if you know the density of a substance, that helps you find out what substance it is (and which substances it definitely is not). Density is one of the properties that you can use to identify a substance. The density also helps decide what uses a substance is suitable for (figure 2).

figure 2 Ladders are often made of aluminium. Aluminium is a lightweight and strong substance.

You can find the densities of various substances in table 1. You can see for instance that metals can have very different densities. Aluminium is a lightweight metal with a density of 2.7 g/cm³. Gold is more than seven times heavier, with a density of 19.3 g/cm³. It is therefore very easy to tell gold and aluminium apart by their densities.

table 1 Densities of various substances.

substance	density (g/cm³)	substance	density (g/cm³)
alcohol	0.80	lead	11.3
aluminium	2.7	air	0.001293
petrol	0.72	brass	8.5
glass	2.6	Perspex	1.2
gold	19.3	steel	7.8
helium	0.000178	sugar	1.6
ice	0.92	turpentine	0.84
iron	7.9	pine	0.58
table salt	2.2	water	1.0
carbon dioxide	0.00198	water vapour	0.00060
copper	8.96	silver	10.5
mercury	13.5	zinc	7.2

DETERMINING DENSITY

EXP 6+7

To determine the density, you do not necessarily need an object of 1 cm³. It works just as well with a bigger object. You can imagine splitting the object into blocks of 1 cm³. The question is then what the mass would be of a single block of 1 cm³.

Figure 3 shows a block of brass weighing 34 g. In your mind, you can split this block into four smaller blocks of 1 cm³. If you split the 34 g over four blocks, each block will have $\frac{34}{4}$ = 8.5 g. The density of brass is therefore 8.5 g/cm³.

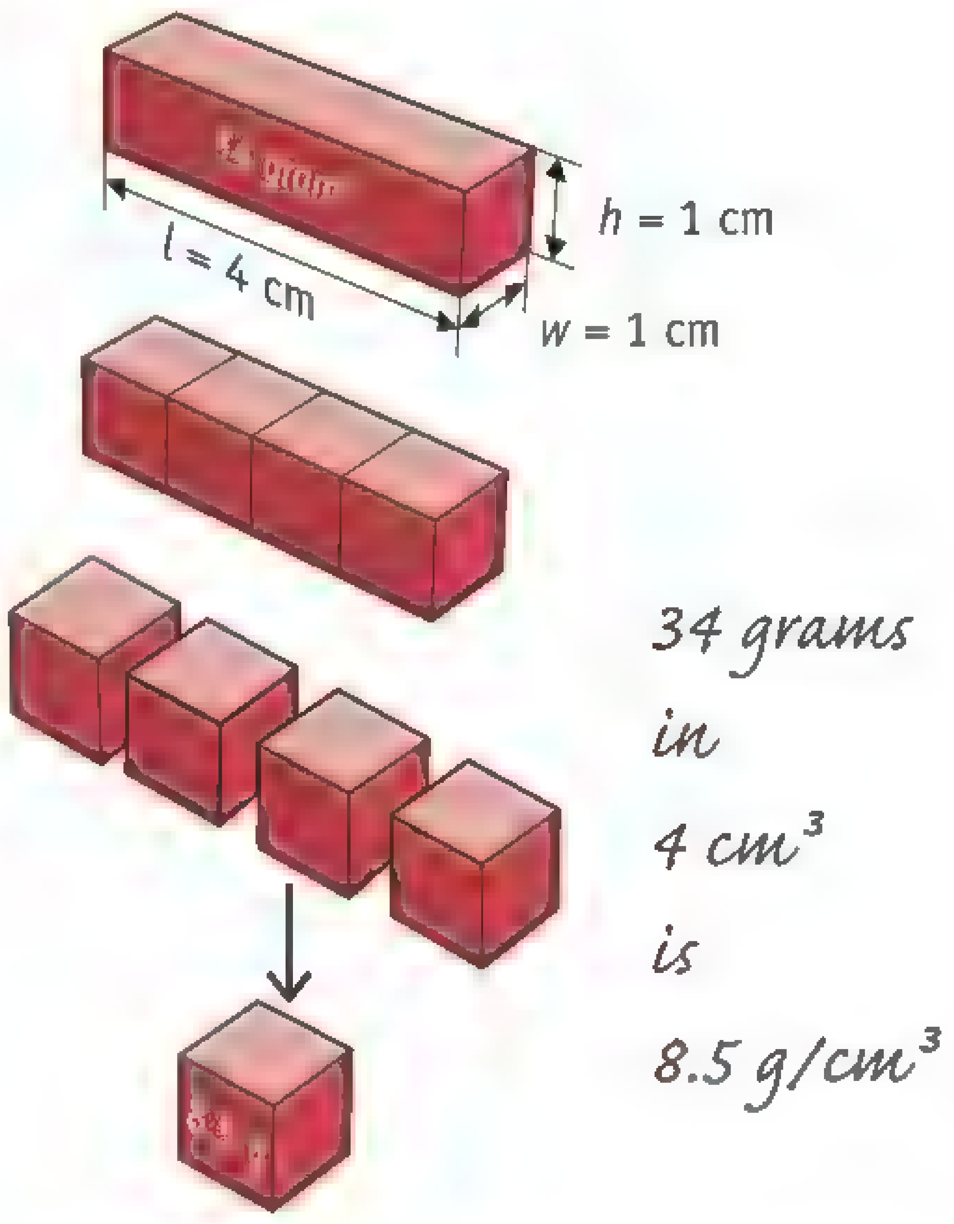


figure 3 This is how you can calculate density.

This is a method that always works: divide the mass (in g) by the volume (in cm³) and you will get the density in g/cm³. You can also write that as a formula:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Or in symbols:

$$\rho = \frac{m}{V}$$

where:

- ρ (rho, pronounced to rhyme with 'go') is the density in grams per cubic centimetre (g/cm³);
- m is the mass in grams (g);
- V is the volume in cubic centimetres (cm³).

EXAMPLE EXERCISE 1

Miranda has a gold-coloured bracelet with a mass of 78 g and a volume of 5.0 cm^3. Calculate whether this bracelet might be made of pure gold.

given $m = 78$ g
$V = 5.0$ cm^3

required $\rho = ?$

working $\rho = \frac{m}{V}$

$= \frac{78}{5.0} = 15.6$ g/cm^3

The bracelet can therefore not be made of pure gold, because that has a density of 19.3 g/cm^3 (see table 1). The bracelet could however be mostly made of gold.

SINKING AND FLOATING ON AND IN WATER

A piece of pine wood floats on top of the water. As you can see in table 1, pine is less dense than water (its density is smaller). Objects float on water if the density of the object is less than the density of water (1.0 g/cm^3).
A silver ring sinks in water. Objects with a density greater than water will sink in water. Just occasionally, the density of an object may be exactly the same as water. In that case, it will just hang in the water and float with it.

Practice the concepts using the *Flash cards*.

EXTRA A WEATHER BALLOON

To predict the weather accurately, it is important to have information about the air's temperature, pressure and humidity high up in the atmosphere. Dutch weather scientists at the KNMI do that once a day by releasing a large balloon containing helium. It has measuring instruments attached: it is a weather balloon (figure 4). A weather balloon like this rises to a height of 20 to 25 km. During the flight, measurements are constantly sent back to the weathermen on the ground.

Helium is a gas with a very low density ($\rho = 0.000178$ g/cm^3). A balloon will rise if its density is less than that of the air ($\rho = 0.001293$ g/cm^3).
Substances and objects that have a lower density than the gas they are in will float upwards. A weather balloon floats in air, in just the same way as a block of pine ($\rho = 0.58$ g/cm^3) floats on water ($\rho = 1.0$ g/cm^3).

figure 4 A weather balloon with measuring instruments.

COURSE MATERIAL

1 Fill in the missing words and symbols in table 2.
See the skills section on *Working with variables and units.*

table 2 Variables and units.

variable	symbol	[illegible]	[illegible]
length		metre	
	m		kg
		litre	
		grams per cubic centimetre	

2 Suppose your teacher gives you an exercise about determining the density of brass. You are given a rectangular block of brass to work with.

- **a** What two variables will you measure first?
- **b** What measuring instruments do you need for this?
- **c** What formula will you then use to calculate the density?
- **d** Finally, what units will you put after the result?

3 Which metal in table 1 has:

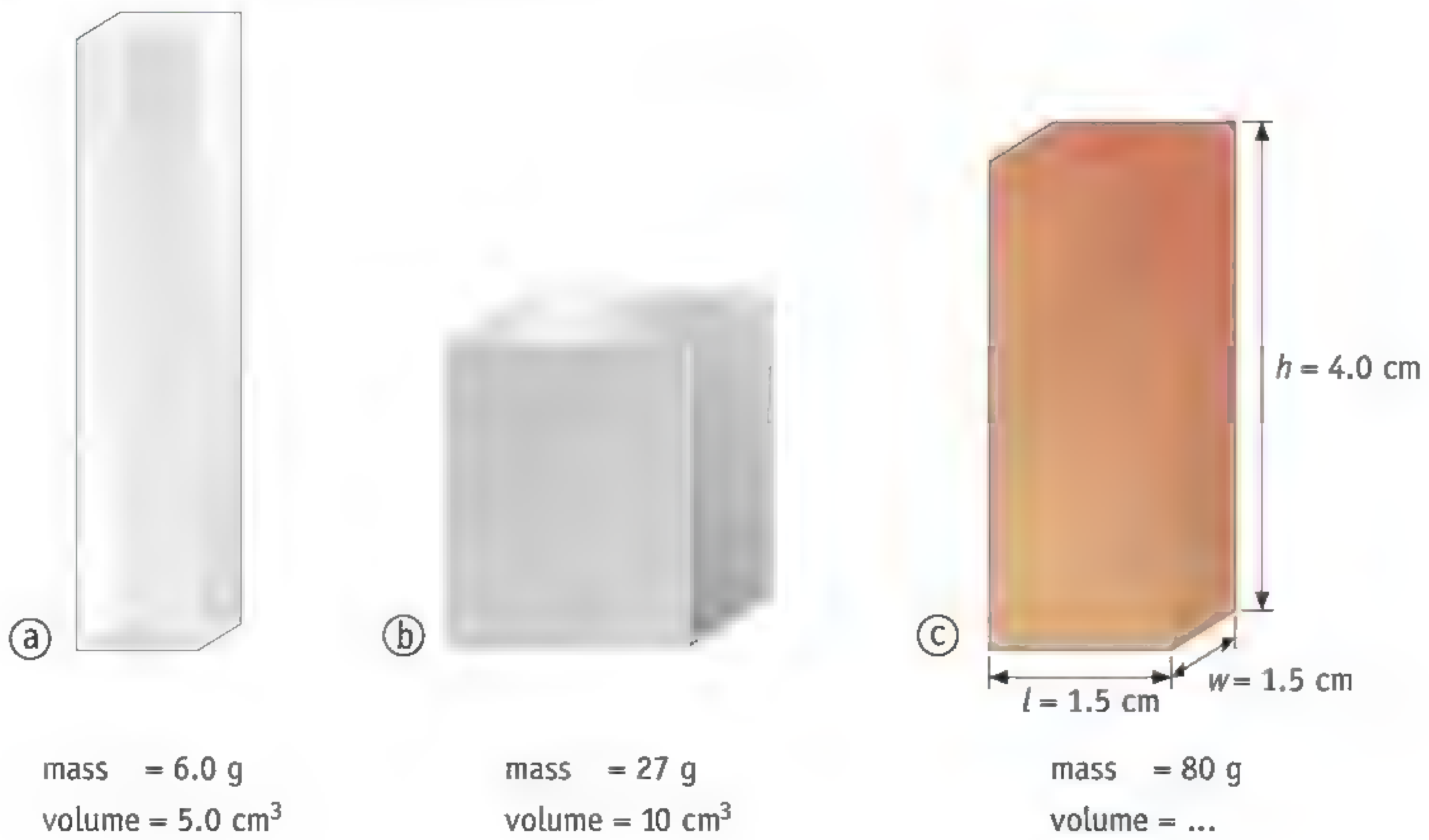
- **a** a density of 11.3 g/cm^3?
- **b** the highest density?
- **c** the lowest density?

IN PRACTICE

4 Figure 5 shows three blocks that are each made of a pure substance.

- **a** Calculate the density of the substances that each of these objects is made of to one decimal place. Show all your calculations.
- **b** For each of these objects, write down what substance it might be made of. Use table 1.

figure 5 Three rectangular objects.



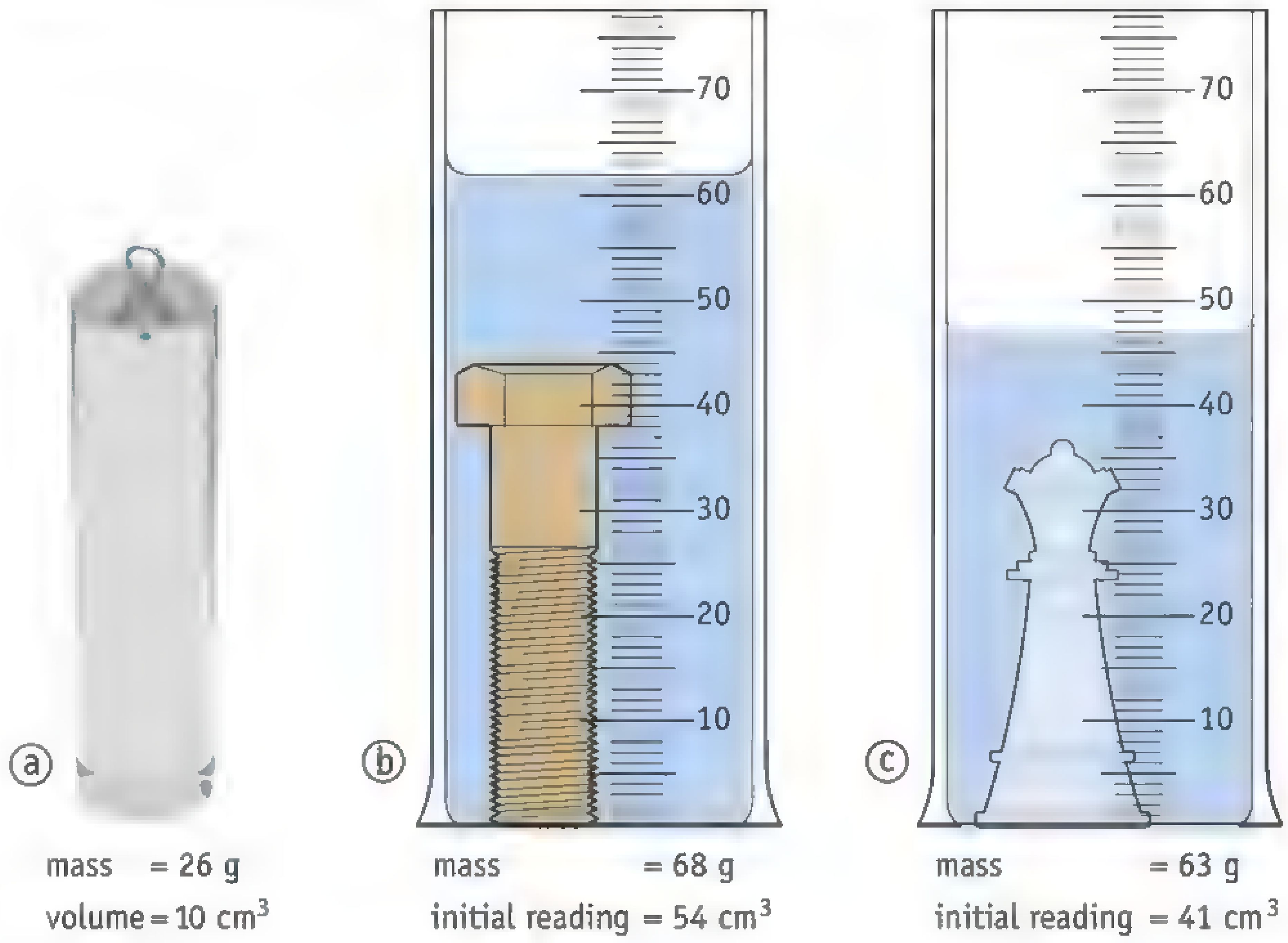
5

Three more objects are shown in figure 6.

a Calculate the density of the substances that each of these objects is made of to one decimal place. Show all your calculation steps.

b For each of these objects, write down what substance it might be made of. Use table 1.

figure 6 A cylinder and two irregularly shaped objects.



6

Mitchell has measured the masses and volumes of four objects. He has shown his measurement results in table 3.

a Calculate the density of each object.

b Which of the objects might be made of the same substance?

c What substance might it be?

table 3 Volume and mass.

volume (cm^3)	mass (g)
9.5	75.0
6.8	48.3
7.2	56.8
4.5	35.5

7

On a shelf in the supermarket, there are large and small packs of coconut milk.

- On the larger packs, it says: 1000 g | 930 mL
- On the smaller packs, it says: 500 g | 465 mL

a Explain how these numbers show you that both types of pack are filled with the same liquid.

b Work out what volume the manufacturer would have to put on a pack of coconut milk containing 200 g.

8

A layered cocktail consists of different drinks that are poured carefully one on top of the other (figure 7).

a What order do the drinks have to be poured into the glass in?

b Why does each drink have to be poured in extremely carefully?

c The drinks consist mostly of water and sugar.
Where will you find a drink containing not much sugar and a lot of water?
- ○ A At the top of the glass.
- ○ B At the bottom of the glass.
- ○ C Impossible to say.

d Explain how you got your answer to Exercise (c).

figure 7 A layered cocktail with liquid honey, peppermint syrup and unsweetened apple juice.

★ 9

A kitchen measuring jug has graduations in grams for flour and sugar. This lets you measure out quantities of these ingredients without needing scales.
The mark for 300 g of flour is lower than the mark for 300 g of sugar.
Explain which of the two ingredients has the lower density (on average).

★ 10

A glass beaker filled to the top with water has a mass of 243 g (figure 8a). Tommy lowers a metal block into it on a thin wire (figure 8b) and then measures the mass of the beaker again: 294 g. Finally, he lifts the block out again and measures the mass of the beaker again with the remaining water: 213 g (figure 8c).

a How many grams of water have overflowed from the glass beaker?

b Calculate the mass of the metal block.

c What is the volume of the metal block?

d Calculate the density of the metal. Round the value off to one decimal place.

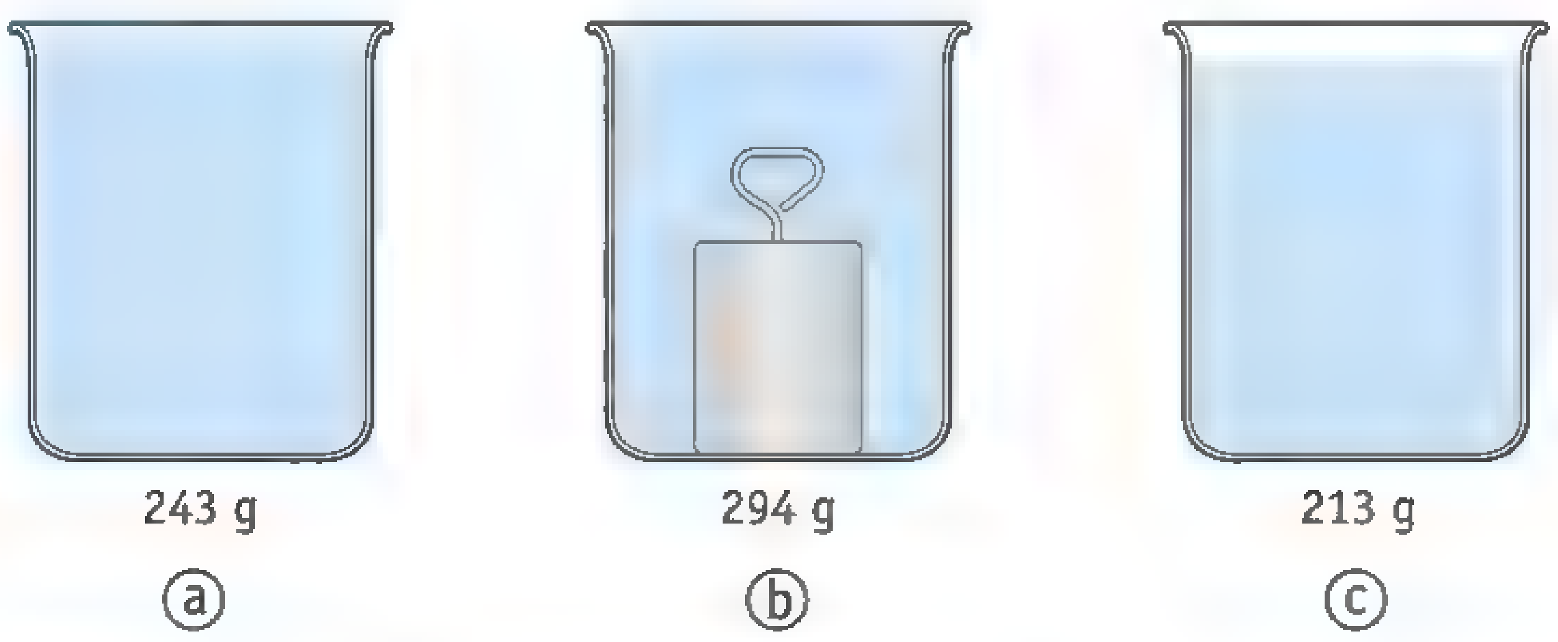


figure 8 What is the density of the metal?

Test what you know with *Test yourself*.

EXTRA A WEATHER BALLOON

11 Eileen fills two balloons with gas: one with helium and one with carbon dioxide. Explain how you can tell which gas is in which balloon.

12 Air expands when you heat it. The volume increases, but the mass remains the same.

- **a** Explain why the density of air decreases when you heat it.
- **b** The hot air balloon in figure 9 is rising. Explain why.

figure 9 A hot air balloon with a burner.

13 The higher you go, the lower the air density gets.

- **a** Explain why a weather balloon filled with helium stops rising once it reaches a certain height.
- **b** How might you describe it if the balloon is no longer rising?

Experiments

EXPERIMENT 1 DISTINGUISHING BETWEEN SUBSTANCES

30 minutes

Introduction

When the police raid a drugs laboratory, they often find all sorts of substances there. To determine what the substances are, the police have a special investigations department. You will be doing something very similar in this experiment, but using harmless substances. You will be given twelve bottles containing substances, without knowing what any of them are. You must use the substance properties to identify as many of the substances as possible.

Goal

This experiment teaches you to identify substances using their properties.

Requirements

- ☐ twelve substances in bottles

Doing the experiment and writing it up

- You will be given twelve bottles. You may open the bottles to smell them. You must definitely not taste the substances!

1 Fill in the details of the twelve substances in table 1. Write down the name of the substance (if you know it).

2 Have a look at the data in the table.

a Which substances are metals?

....

b Which substances are transparent?

....

table 1 Twelve substances and their properties.

number	colour	odour	*solid / liquid / gas*	special aspects	name
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					

EXPERIMENT 2 INVESTIGATING SUSPENSIONS AND SOLUTIONS

15 minutes

Introduction
You come across various sorts of mixtures in daily life. Tea (without milk) and coke are examples of solutions. Orange juice and paint are examples of suspensions.

Goal
In this experiment, you will learn to recognize two differences between solutions and suspensions.

Requirements
- ☐ test tube with water + ink
- ☐ test tube with water + charcoal
- ☐ 2 test tubes (empty)
- ☐ 2 funnels
- ☐ 2 filter papers

Doing the experiment and writing it up
- Shake the test tube with water + ink. Look immediately afterwards to see if you can see through the mixture.
- Shake the test tube with water + charcoal. Look immediately afterwards to see if you can see through the mixture.

1 Can you see through the diluted blue ink? *yes / no*

2 Is this a solution or a suspension? *solution / suspension*

3 Can you see through the mixture of charcoal and water? *yes / no*

4 Is this a solution or a suspension? *solution / suspension*

- Fold the filter papers as shown in figure 1 and put them in the funnels.
- Moisten the filters; they will then stay in place better in the funnels.
- Put the funnels in the empty test tubes.
- Shake the mixture of water + ink and pour it carefully into one filter.
- Shake the mixture of water + charcoal and pour it carefully into the other filter.
- Watch closely to see what happens.
- Wait until nothing more is dripping out of the filters.

5 What do the liquids in the tubes underneath look like?

....

6 In which of the filters did a solid residue remain behind?

....

7 What substance or substances are in the residue?

....

8 What substance or substances definitely went through the filter in the water + ink mixture?

....

9 What substance or substances definitely went through the filter in the water + charcoal mixture?

....

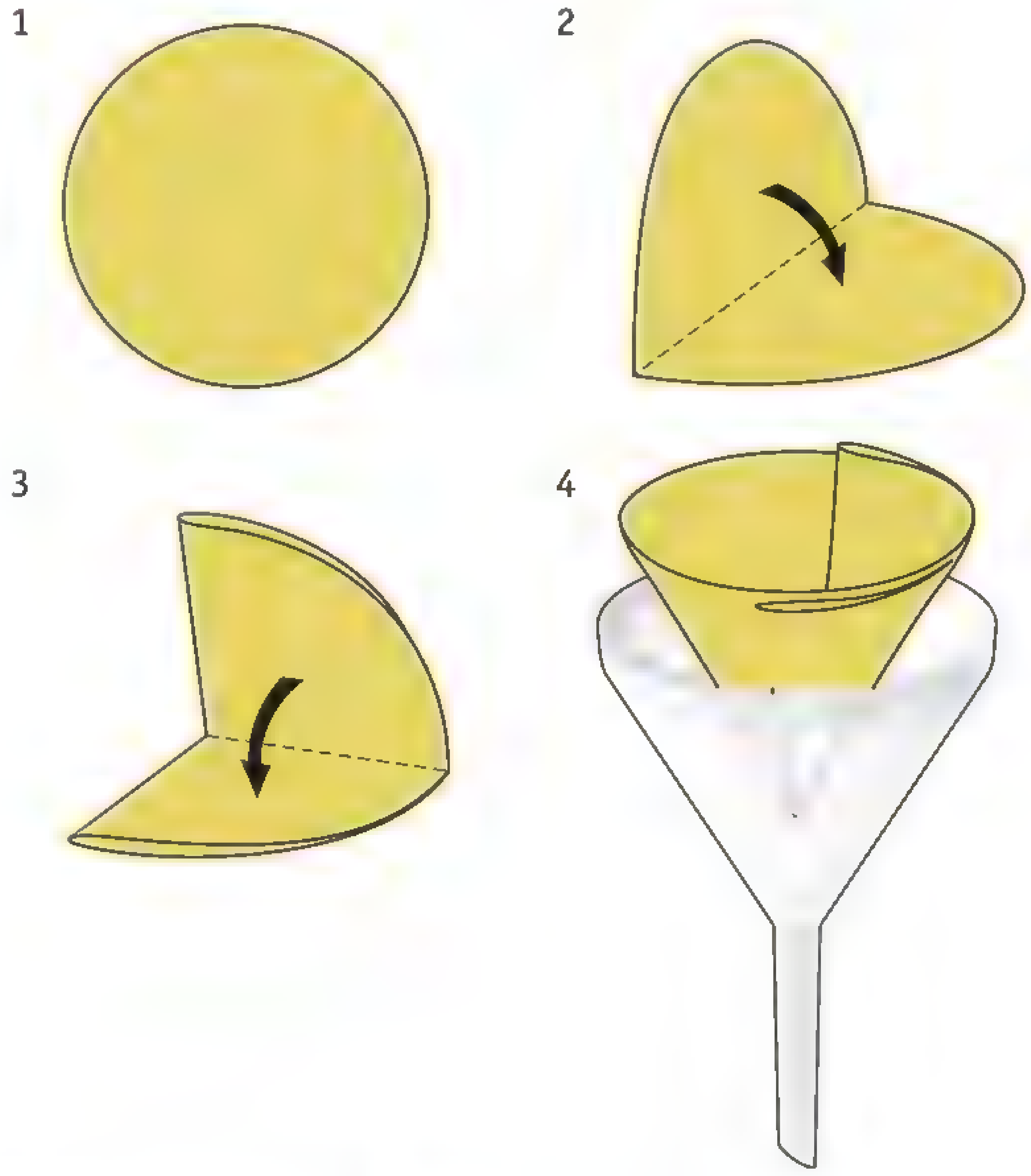


figure 1 How to fold a filter.

EXPERIMENT 3 EXTRACTING ROCK SALT

30 minutes

Introduction

Rock salt is extracted (mined) by pumping hot water into the ground. Deep underground, a mixture of water and rock salt is created, known as brine. The brine is then pumped up, after which the salt is extracted from the brine.

Goal

In this experiment, you are going to heat brine until rock salt is left over.

Requirements

- ☐ rock salt
- ☐ distilled water
- ☐ glass beaker
- ☐ stirring rod
- ☐ test tube
- ☐ funnel
- ☐ filter paper
- ☐ small porcelain/steel crucible
- ☐ Bunsen burner
- ☐ tripod
- ☐ wire mesh
- ☐ matches/lighter

Doing the experiment and writing it up

Dissolving and filtering

- Put a couple of spoonfuls of rock salt in the beaker.
- Add a little hot water to the rock salt and stir it thoroughly.
- Filter the liquid and collect the filtrate in a test tube.

Evaporation

- Put the gauze (the wire mesh) on the tripod. Put the crucible on the wire mesh.
- Pour a little bit of the liquid from the test tube into the crucible.
- Set the Bunsen burner to a small silent blue flame (figure 2).
- Heat the liquid in the crucible until all the water has evaporated.

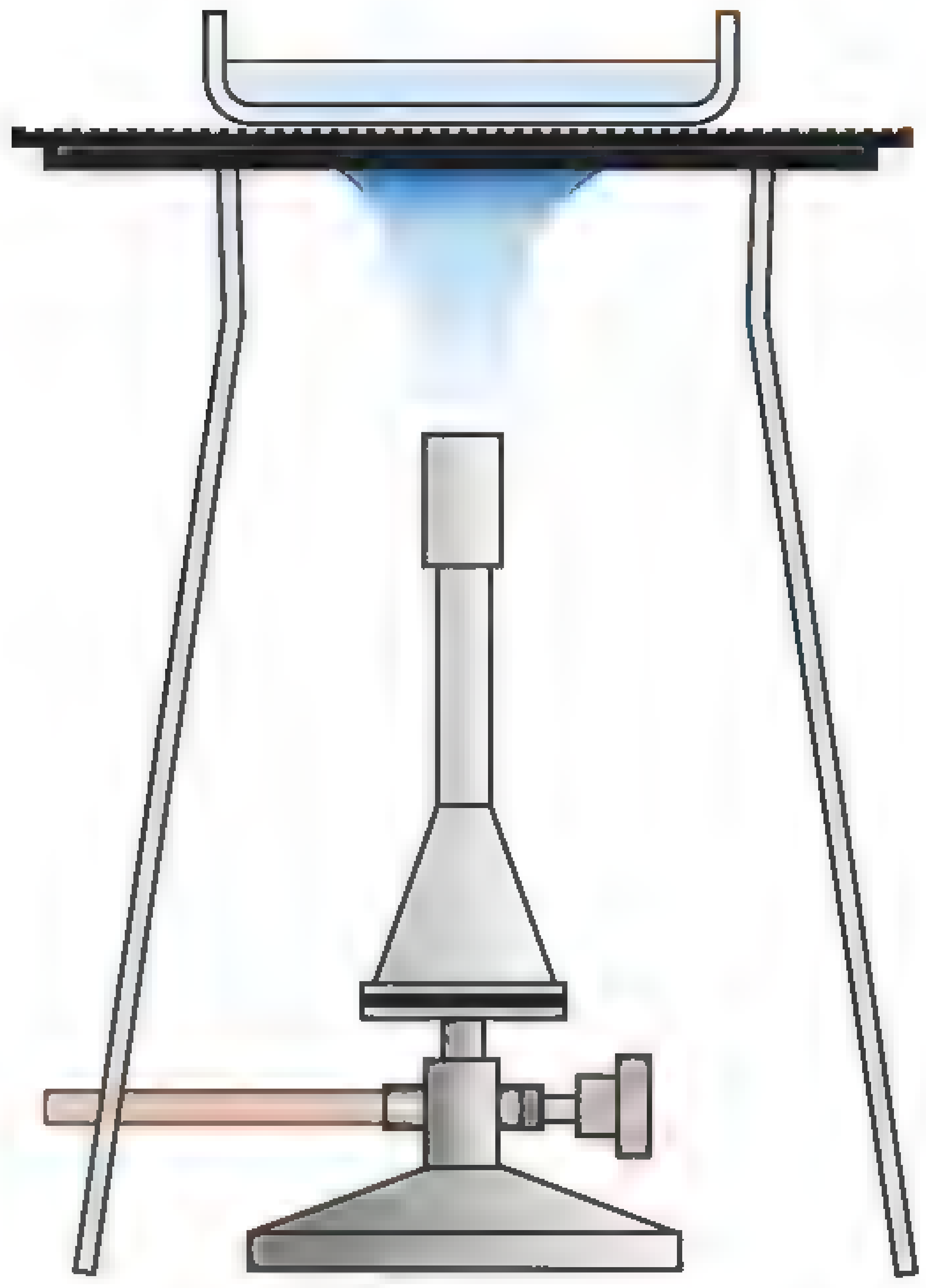


figure 2 The setup for Experiment 3.

Take care! Take the burner out from under the gauze if the liquid starts to spit too much. Make the flame smaller by closing the gas control knob a bit. Then put the burner back under the gauze.

1 Is there any solid material left behind in the filter after filtration?

....

2 Describe the contents of the crucible after evaporation.

....

3 What can you say about the solubility of this substance?

....

EXPERIMENT 4 DETERMINING VOLUME AND MASS

30 minutes

Introduction

You can look at either the mass or the volume when you want to determine the quantity of a substance. In the supermarket, for instance, you will find one-litre packs of milk as well as one-kilogram packs of sugar. Units of volume and mass are also often used side by side in recipes. You may for example see: "Add 250 g mushrooms and 100 mL water."

Goal

In this experiment, you will determine the volumes and masses of four rectangular objects.

Requirements

- ☐ 4 different blocks
- ☐ ruler or drafting protractor
- ☐ scales

Doing the experiment and writing it up

1 Write down what each block is made of in column 1 of table 2.

- Measure how long the sides of the blocks are (in cm).

2 Write the measurements down in the table.

3 Calculate the volume of each block using the formula $V = l \cdot w \cdot h$.
Round the answer off to a whole number and write it down in column 5.

- Determine the mass of each block using the scales.

4 Write down the mass of each block in the final column of the table.

table 2 The measurements for Experiment 4.

object	length	width	height	volume	mass
1					
2					
3					
4					

EXPERIMENT 5 WORKING WITH THE IMMERSION METHOD

15 minutes

Introduction

There is no simple way of calculating the volume of an irregularly shaped object using a formula. For objects like that, you have to use the immersion method.

Goal

In this experiment, you will learn how to determine the volume of two objects using the immersion method.

Requirements

- ☐ measuring cylinder
- ☐ aluminium block
- ☐ pebble

Doing the experiment and writing it up

- Fill the measuring cylinder with water to about two thirds full. Read the level of the water (in cm^3).

See the skills section on *Reading measuring instruments*.

1 Complete:

The starting level is .... cm^3.

- Carefully allow the aluminium block to sink beneath the surface of the water (figure 3).
- Read the level of the water again (in cm^3).

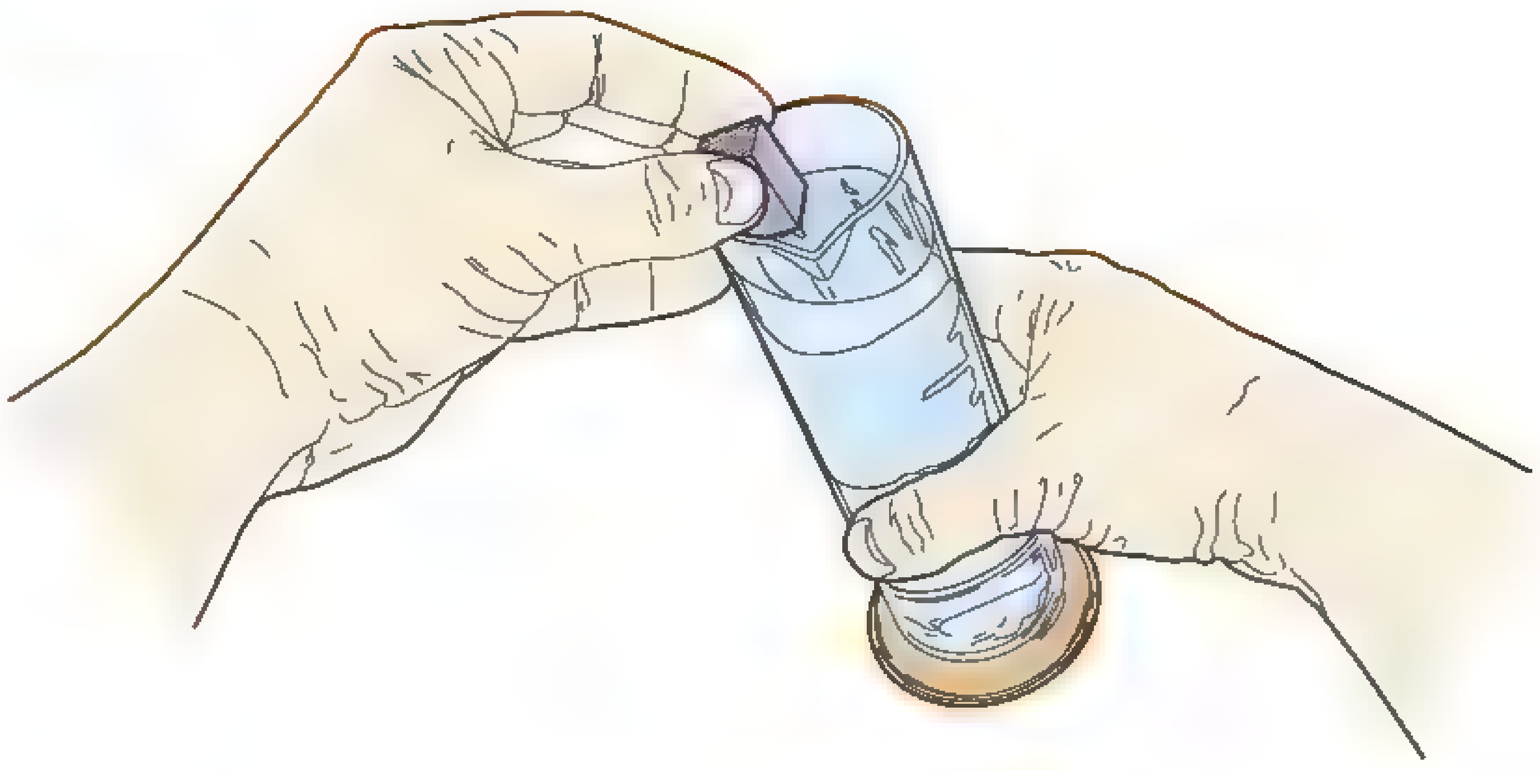


figure 3 Keep the measuring cylinder tilted as you lower the block into it.

2 Complete:

The final level is .... cm^3.

3 What is the volume of the block?
Complete:
volume of block = final level minus starting level

V = ... – ....

V = ...

- Now determine the volume of an irregularly shaped object. In this case, it is a pebble.

4 Calculate:
volume of pebble = final level minus starting level

V = ... – ....

V = ...

EXPERIMENT 6 DETERMINING DENSITY

45 minutes

Introduction
Researchers can often say exactly what substance is involved if they know the density. You can calculate the density by dividing the mass (in g) by the volume (in cm^3). This gives you the density in g/cm^3.

Goal
Determining the density lets you find out what substance an object is made of. You are going to do that in this experiment.

Requirements
- ☐ measuring cylinder
- ☐ ruler or drafting protractor
- ☐ scales
- ☐ 5 objects

Doing the experiment and writing it up

- Determine the mass and volume of the substances that the five objects are made of.

1 Write your measurements down in table 3.

2 Use the formula to calculate the density of each object.
Round the results off to one decimal place.
Write the results down in the correct place in the table.

- Compare the densities that you have determined against the densities in table 1 of Section 4.

3 Write down in the table the substance that each of the objects is probably made of.

table 3 The measurements for Experiment 6.

object	mass (g)	volume (cm^3)	density (g/cm^3)	substance
1				
2				
3				
4				
5				

EXPERIMENT 7 DETERMINING THE DENSITY OF A LIQUID

30 minutes

Introduction

You can determine the density of a liquid by dividing the mass of the liquid by its volume.

Goal

In this experiment, you will be determining the densities of two liquids.

Requirements

- ☐ scales
- ☐ measuring cylinder
- ☐ distilled water
- ☐ methylated spirits

Doing the experiment and writing it up

- Think how you can determine the mass and the volume of a quantity of liquid.

1 Write down the measurements and calculations that you are going to do, and in what order.

....

....

....

....

- Determine the densities of water and methylated spirits to one decimal place.

2 Write down all the measurements, calculations and results.

....

....

....

....

....

....

....

....

....

....

EXPERIMENT 8 CARRYING OUT RESEARCH: SALT IN RECLAIMED LAND

45 minutes

Introduction
Suppose a dyke has broken and a large area of farmland has been flooded. This means salt has ended up in the soil. That is a problem when growing crops, which means losses for the owner of the land. The land owner's insurance company asks for a report saying (among other things) how much salt ended up in the soil. A research laboratory is called in to investigate. In this exercise, you are the lab technician who has to carry out the study.

Goal
In this experiment, you will be determining the amount of salt in a soil sample. The result has to be given as grams of salt per kilogram of soil.

Requirements
For this experiment, you have to think up for yourself what equipment you will need.

Doing the experiment and writing it up
- Think about how you can give the most reliable answer to the question. What are you going to measure, what items will you need for the experiment and how are you going to work out your answers afterwards?

1 Make a work plan for this study.

See the skills section on *Doing research*.

- The work plans will be discussed with the rest of the class in the next lesson. If necessary, you can make improvements to your own work plan after that.
- Then carry out the experiment.

2 Write down all the measurements, calculations and results.

- Your teacher will tell you whether or not you have to write up a report on this experiment.

Gold: genuine or fake?

Gold is a yellow and shiny metal. But 'all that glitters is not gold'. In the past, when gold coins were still in circulation, market traders would sometimes bite a gold coin to see if it was real. Pure gold is so soft that you would leave tooth marks in it. It seems as if elite athletes have taken over that habit. At the Olympic Games, the winners always seem to bite their medal for a moment, even if nobody knows why any longer.

Real gold?

When is an object really made of gold? We asked an expert: Jeanne Derksen, a professional jeweller and gold buyer. "Well," she says, "if what you mean by 'gold' is 100% pure gold, the answer is 'never'. Coins and jewellery are not made from pure gold, because it is much too soft. It's always an alloy – a mixture of gold with other metals. An alloy is harder and scratches less easily than pure gold."

"Gold isn't always yellow either," explains Ms Derksen. "Pure gold is, of course, but gold alloys can be all sorts of colours. You can get white gold, red gold, green gold and even purple gold. The colour you get depends on the metals in the mixture. Gold jewellery is often made of alloys that contain a lot of silver. That makes them bright yellow, unlike pure gold, which is a warm orange-yellow. Alloys with a lot of copper, on the other hand, have a red shine."

"A piece of jewellery made of 14-carat gold in is fact just a little more than half gold."

Hallmarks

So how can you find out how much gold an object contains? Ms Derksen explains: "You can tell that from the hallmark that is stamped into it. Every country has its own hallmarks. The Dutch hallmark shown in figure 1 means for instance that the alloy used contains 750/1000 pure gold, i.e. it is three quarters or 75% pure."

"But," she says, "jewellers have their own way of indicating the gold content. They use a special unit: the carat. This is a scale that goes from 0 to 24 carats. 0 carats is 0% gold, 6 carats is 25% gold, 12 carats is 50% gold, 18 carats is 75% gold and 24 carats is 100% gold. If you see a Dutch 750 hallmark on an object, a jeweller will say that it is made of 18-carat gold."

figure 1 The Dutch hallmark for 75% gold.

"In the United States, '10K gold' – which is actually less than half gold – is very popular."

The gold content of 'gold'

Four types of alloy may be used in the Netherlands for gold jewellery. Each type of alloy has its own hallmark (figure 2). "These four alloys are simply called 'gold' in the shop," explains Jeanne Derksen, "although it's not pure gold, of course. A piece of jewellery made of 14-carat gold is in fact just a little more than half gold."

Testing gold

But how can you find out if it is correct? After all, surely hallmarks can also be forged? Ms Derksen says that she first has a good look at the object. "Sometimes you can see from a worn patch that it is gilded copper or silver. I also have a good look to see if the metal has been corroded. If so, you know that the gold content can't be very high."

Then she shows how she would test a gold bracelet. She puts three vials on the table (figure 3). "Careful with those," she says, "they are corrosive acids that you most definitely mustn't get on your clothes or on your skin." She points to a vial labelled '14K'. "We call this liquid '14-carat water'. But don't be fooled – it's nitric acid, very nasty stuff. Most metals dissolve in it quickly, but gold that is 14 carats or purer can withstand it."

Ms Derksen takes the bracelet and rubs it firmly over a touchstone, a square piece of slate with a smooth surface. In figure 4, you can see that it has left a yellow streak on the stone. She puts a few drops of the testing solution carefully onto the mark, but nothing happens. "That's exactly what you want to see," she says. "If the streak doesn't dissolve, then you know that it's real gold, at least 14 carats."

She makes a new mark on the touchstone and now takes the small bottle labelled '18K'. This time, the yellow streak disappears immediately when she puts a couple of drops of the test liquid on it. "You can see that the gold does dissolve now," she says. "That means that the gold content is less than 18 carats. It's probably 14-carat yellow gold, which is a popular alloy."

Density

"This was just a quick initial test," says Ms Derksen, "but it gives you

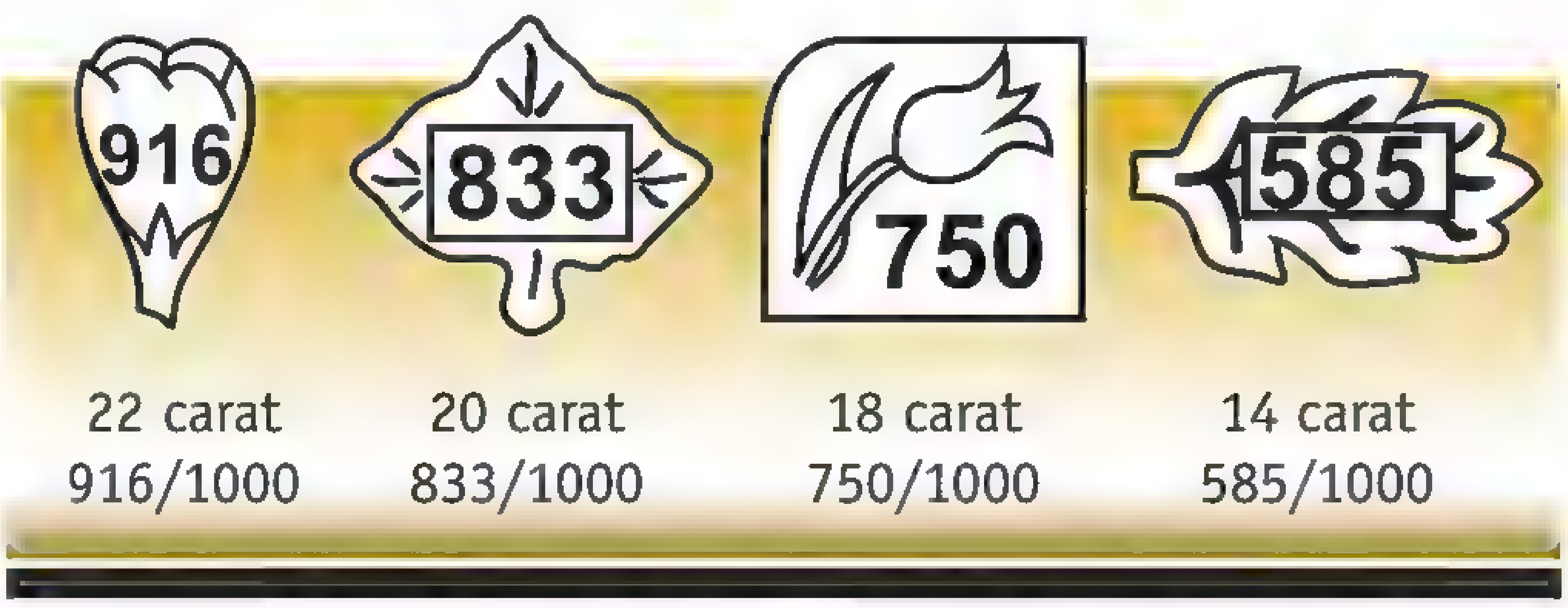


figure 2 The hallmarks for the four alloys that are allowed to be used in the Netherlands.

figure 3 Test liquids for determining the gold content in an alloy.

an idea of how the gold content can be tested. If the result matches the hallmark, that's usually enough to be sure. If not, you can also determine the density as an extra check. That's another method that also gives reliable results."

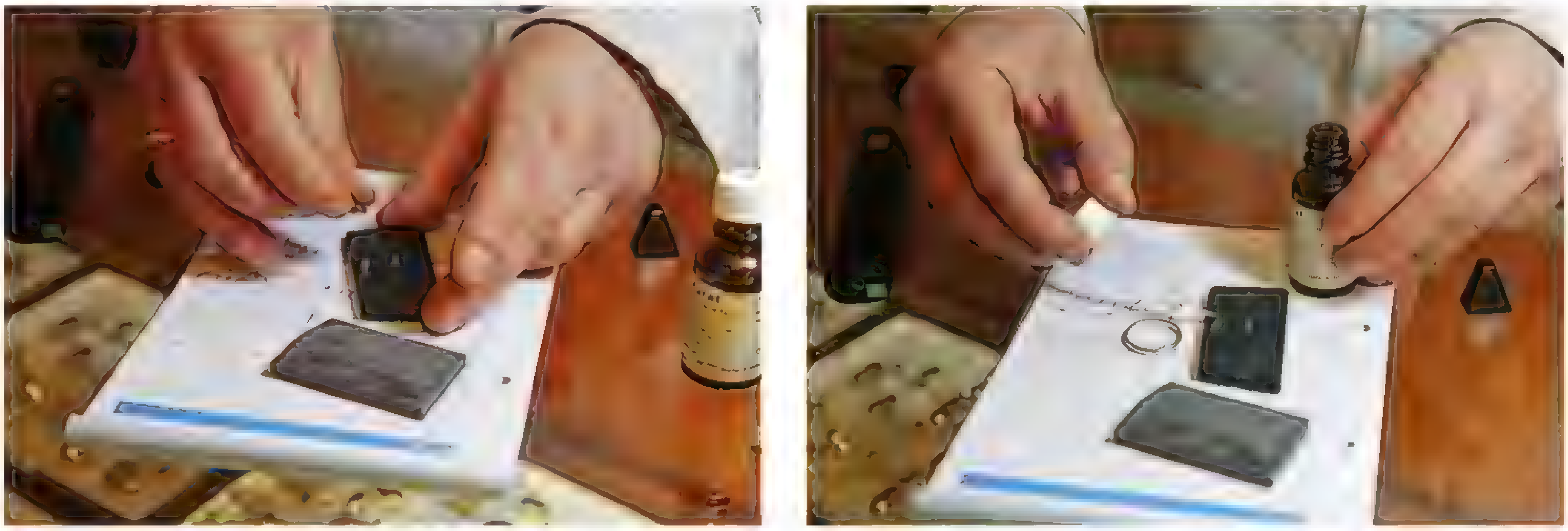
Jeanne Derksen shows a table that gives the densities of various gold alloys (table 1). "Most forgeries use silver and copper," she tells us. "But gold is extremely heavy; its density is much higher than silver or copper. Which is useful for us. A forgery can look deceptively realistic, particularly if you don't work with gold every day. But if you determine the density, a forgery will be shown up for what it is, every time."

Believe it or not, an Olympic gold medal would also fail the test. The gold medals from the 2016 Olympics, for example, only contain 1.2% gold – the rest is silver. A medal weighing 500 g contains just 6 g of gold, in a thin layer on the outside. It's just as well that the athletes don't bite down hard on their gold medals. Otherwise they might lose a few teeth...

table 1 The densities of a number of gold alloys (g/cm^3).

	585 / 14K	750 / 18K	916 / 22K	100 / 24K
yellow gold	13.6	15.5	17.8	-
red gold	13.0	15.0	17.6	-
pure gold	-	-	-	19.3

figure 4 Determining the gold content in an alloy.



EXERCISES

1 The text lists three ways of testing gold objects.
What property of the substance gold helps you recognize 'real gold':

a when you bite down firmly on an old gold coin?
b when you use nitric acid to test a 'gold streak' on a touchstone?
c when you measure the mass and volume of a gold object?

2 Lee-Anne bought a bracelet on holiday that was made of '9-carat gold'.

a Can this alloy be called 'gold' in the Netherlands? Explain your answer.
b Show that 9 carats is the same as 375/1000, or 37.5%.

3 The density of 18-carat 'yellow gold' is greater than the density of 18-carat 'red gold'.

a Which metal is pure gold alloyed with
- to give the bright yellow colour of 'yellow gold'?
- to give the red sheen of 'red gold'?

b Compare the densities of the metals that you have given in your answer to Exercise (a).
Why is 'yellow gold' denser than 'red gold'?

Course material overview

2.1 SUBSTANCES IN THE HOME

REMEMBER

- The characteristics that let you recognize a substance are called its properties. Examples of the properties of substances are odour, colour, taste and flammability.
- A substance can be hazardous in various ways:
  - if you breathe it in;
  - if you swallow it;
  - if you get it on your skin, in your eyes or on your clothes;
  - if you let it get close to a flame;
  - if you mix it with certain other substances.
- There are warnings on the packaging of hazardous substances. The hazards are also indicated by pictograms that are known as 'hazard symbols'.

CONCEPTS

flammability
The property of a substance that says how easily a substance can burn.

hazard symbol
A symbol (pictogram) showing what danger you have to be careful about.

property of a substance
Something typical or characteristic about a substance that you can use to tell it apart from other substances.

2.2 PURE SUBSTANCES AND MIXTURES

REMEMBER

- A mixture contains several substances. A pure substance consists of just a single substance.
- Substances are made up of extremely small particles. These particles are called molecules.
- The sizes of molecules are given in nanometres. 1 nm = 0.000000001 m.
- If you mix a solid substance with a liquid and the solid substance disappears, it has made a solution. Solutions are always clear. You can see through them.
- If a liquid mixture is cloudy (opaque), it therefore cannot be a solution. This type of mixture is called a suspension.
- You can use hot water or other liquids to separate out odours, colorants and flavourings from solid substances. This creates a solution. The process is called 'extraction'.
- You can use a filter to separate out a solid substance from a liquid. There are very small holes in a filter. The solid substance that stays behind in the filter is called the residue. The liquid that passes through the filter is called the filtrate. The process is called 'filtration'.

CONCEPTS

extraction
A method of separating soluble solid substances from insoluble ones.

filtrate
The liquid that passes through the filter during filtration.

filtration
Separation method for separating a solid from a liquid using a filter.

mixture
A substance that is made up of two or more types of molecules.

molecules
Very tiny particles that make up substances.

pure substance
A substance that consists of only one type of molecule.

residue
The particles left behind on the filter after all the fluid has run through it.

solution
A mixture of two or more substances in which the dissolved substance has been totally absorbed into the solvent.

suspension
A liquid with a finely divided powder floating in it.

2.3 MASS AND VOLUME

REMEMBER

- Scales let you determine the mass of and object or a quantity of a substance. Mass is measured in units of kilograms. 1 kg =1000 g.
- A measuring cylinder lets you determine the volume of a quantity of liquid. The volume is the space that the liquid takes up. You measure volumes in litres (L) or millilitres (mL). 1 L = 1000 mL.
- You can calculate the volume of rectangular objects using the formula $V = l \cdot w \cdot h$.
- You can calculate the volume of cylindrical objects using the formula $V = \pi \cdot r^2 \cdot h$
- You can determine the volume of irregularly shaped objects by the immersion method.

CONCEPTS

immersion method
A method for determining the volume of an irregularly shaped object.

mass
Variable telling you how much substance there is in an object.

volume
Variable telling you how much space an object or substance takes up.

2.4 DENSITY

REMEMBER

- To determine which of two substances is 'lighter', you can make a fair comparison by determining what the mass of a bock of 1 cm^3 of each substance would be. The block with less mass is made of the 'lighter' substance.
- The density of a substance says what the mass is of 1 cm^3 of that substance. Density is a property of a substance.
- You can calculate the density of a substance using the formula $\rho = \frac{m}{V}$.
- Objects float on water if their density is less than the density of water (1.0 g/cm^3).
- Objects sink in water if their density is greater than the density of water.
- Objects float in or under water if their density is the same as the density of water.

CONCEPTS

density
The mass of 1 cm^3 of a substance.

Go to the *Flash cards* and the *Diagnostic test*.

3 Water

THE WEATHER
Water is closely involved in the weather. A party seems much less fun if it suddenly starts pouring with rain. People who enjoy their winter sports cannot go skiing if there is not enough snow. Fog and freezing rain can disrupt traffic enormously. And when it's really hot, water can also help cool you down.

1 Ice, water, water vapour

LEARNING OBJECTIVES

3.1.1 You can recognize the three phases of water in practice.
3.1.2 You can describe the three phases in which water can occur using the particle model.
3.1.3 You can use the particle model to explain why ice and many other solid substances have characteristic crystal structures.
EXTRA 3.1.4 You can explain what cohesion and adhesion are.

TAXONOMY	LEARNING OBJECTIVES AND EXERCISES			
	3.1.1	3.1.2	3.1.3	3.1.4
Remembering		2abc		10ab, 11ad
Understanding	1, 4ab, 5, 6ab, 7abc	3		11bce
Using	4c	8ac	8b	
Analysing		9ab		

Rain, snow, mist, hail, frost and dew all look very different. Rain consists of transparent droplets, snowflakes are white and feathery, fog is a thick grey cloud that stops you from seeing much of the world around you, and so on. Nevertheless, all these weather types involve the same substance: water.

SOLID, LIQUID AND GASEOUS

Like many other substances, water can exist in three different states:

- as a **solid substance**: ice;
- as a **liquid**: water;
- as a **gas**: water vapour.

These three states are also referred to as **phases**.

Snow, hail and frost all consist of ice (figure 1). If you pick up a handful, ice will melt in the warmth of your hand and only a little water will remain. Rain, mist and dew consist of water droplets. You can often see the drops clearly in rain and dew, but in fog or mist they are microscopically small.

figure 1 Frost consists of lots of small ice crystals.

The problem with water vapour is that you cannot see it. The term 'water vapour' is often used for a cloud that consists of very small droplets of water, but that is incorrect. A cloud consists of liquid water, even though the individual droplets are so small that you cannot see them. Water vapour is not a mist: it is an invisible gas in the air all around you. A mist of hot water droplets is also often called 'steam'. That's incorrect, actually: steam is hot water vapour. So steam is an invisible gas too.

figure 2 The low air temperature allows small visible 'clouds' to be formed.

There is a relatively large amount of water vapour in the air that you exhale. You do not normally see that. But when the weather is cold, the water vapour in your breath can change into very small droplets of water because your warm breath cools down in the cold outside air. Then you can see a small cloud of mist appearing in front of your mouth (figure 2).

PHASES IN THE PARTICLE MODEL

You cannot see how the molecules in a substance such as water behave. You can try to imagine it, though. You can try to picture what the molecules are doing and how they affect one another. This lets you get an idea of what a substance actually is. This kind of picture is also called a 'model' of the substance.

In physics and chemistry, the **particle model** is widely used. In this model, a substance is always made up of the same molecules, no matter whether the substance is solid, liquid or gaseous. A substance can exist in different phases because the molecules can move in various ways (rather than because the molecules themselves change in any way).

SOLID

In a solid substance, all the molecules have their own fixed positions (figure 3a). The molecules are not entirely still: they are vibrating back and forth around an average 'equilibrium position' without losing their fixed positions with respect to the other molecules. A block of ice therefore has not only a fixed shape but also a fixed volume.

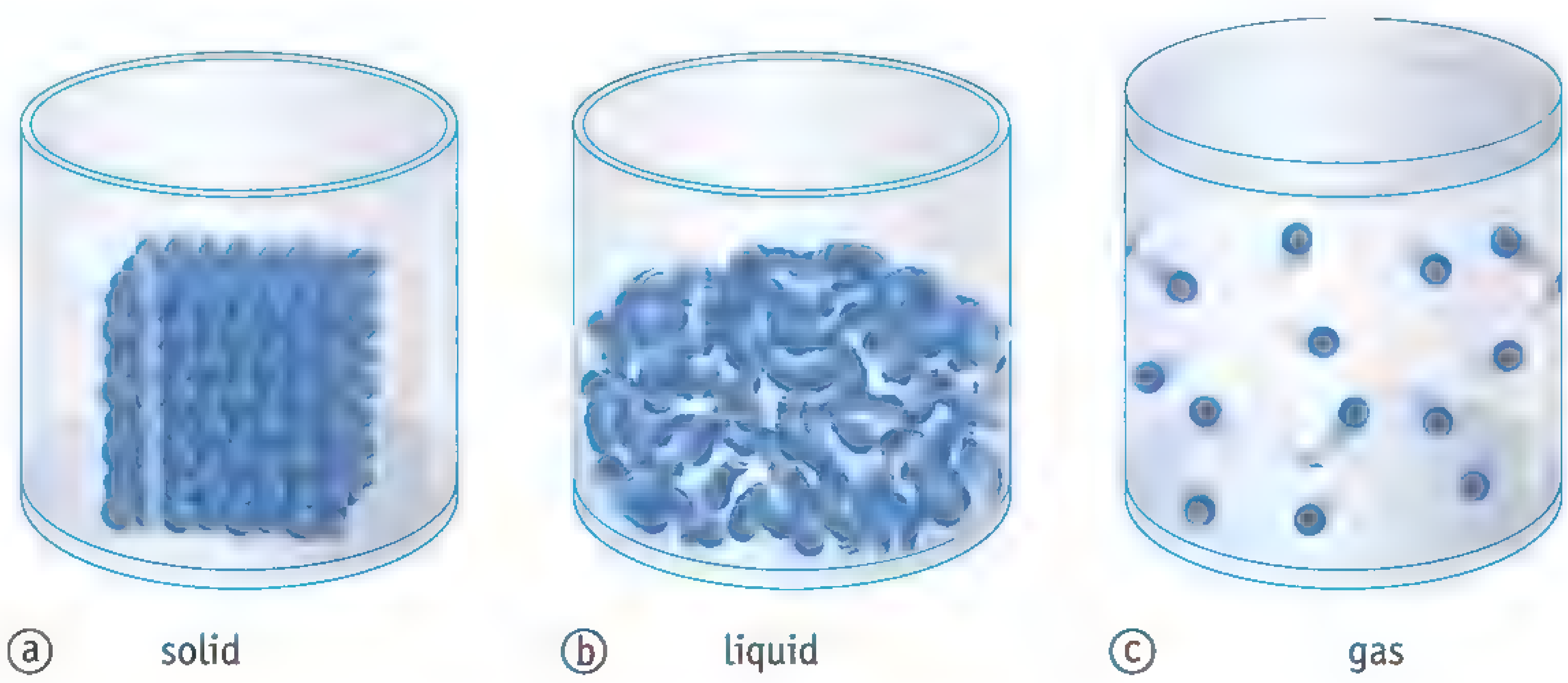


figure 3 The molecules in a solid, a liquid and a gas.

LIQUID

In a liquid, the molecules do not have a fixed position. They can move back and forth past one another in any direction (figure 3b). Because the molecules are not fixed in a given position, a water drop does not have a fixed shape. The molecules do remain as close to each other as possible, though. That means that a drop of water does have a fixed volume.

GAS

The molecules in a gas move freely and independently of one another. They spread out to fill all the space that the gas is confined in (figure 3c). The average distances between them are very large. The molecules do not affect one another, except when they collide. A gas such as water vapour therefore has neither a fixed shape nor a fixed volume.

CRYSTALS

Snow is made up of ice crystals that have all kinds of beautiful shapes. All those shapes have the same type of six-sided structures. This **crystal structure** is typical of ice (figure 4). Many solid substances have their own distinctive crystal structures.

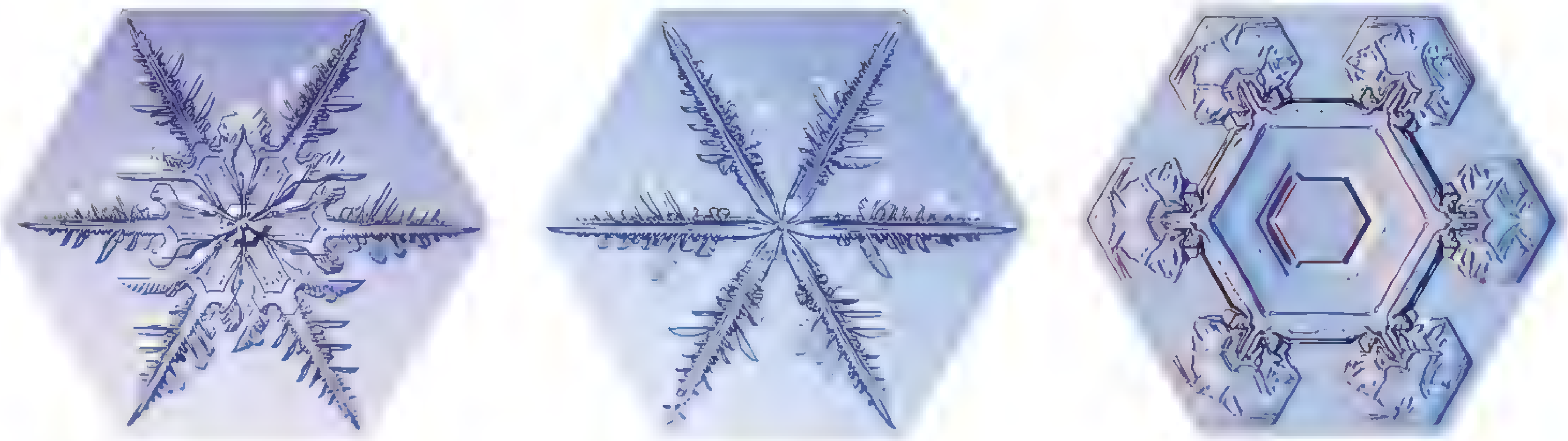


figure 4 The ice crystals in snow have a distinctive hexagonal structure.

The particle model lets you explain why crystals have fixed shapes. Because the molecules in a substance are all identical, they can be 'stacked' in regular patterns, just like the oranges in a supermarket (figure 5). This creates a **crystal lattice** in which every molecule has a fixed position.

Crystals can be microscopically small, but can also be several centimetres in size. A piece of rock crystal is made up of large individual crystals that have grown together. The crystal structure can then be seen clearly with the naked eye (figure 6).

figure 5 A model of a crystal, with oranges instead of molecules.

figure 6 A piece of rock crystal.

Practice the concepts using the *Flash cards*.

EXTRA COHESION AND ADHESION

Molecules of the same substance attract each other. This is known as cohesion. There may also be attractive forces between molecules of different substances. This is known as adhesion. Cohesion is the reason why a water droplet assumes a spherical shape: the molecules pull together as tightly as possible. Adhesion is why a drop of water will hang from a tap (figure 7).

figure 7 A dripping tap: an example of both cohesion and adhesion.

If you dip one end of a sugar cube into water, the cube will draw up water until it is wet through. This is because the adhesive forces (between the sugar molecules and the water molecules) are much greater than the cohesive ones (between the individual water molecules). This means that the water is soon attracted into the small gaps between the sugar granules.

When materials such as kitchen paper or cotton absorb water, this is because the adhesion is greater than the cohesion within the water. Precisely the opposite happens for some other substances. Drops of water retain their shape on a greasy surface, for example, because there is no attraction between fat molecules and water molecules: there is no adhesion, only cohesion.

COURSE MATERIAL

1 What phase is the water in?

A	snow	○		
B	rain	○	○ 1	solid
C	hail	○	○ 2	liquid
D	dew	○	○ 3	gaseous
E	frost	○		
F	mist	○		

2 According to the particle model, how are the molecules moving in:

a a solid?
b a liquid?
c a gas?

3 A water droplet does not have a fixed shape, but it does have a fixed volume. Explain this using the particle model.

IN PRACTICE

4 Figure 8 shows you a kettle of boiling water.

a What phase is the water in at A? How can you see that?

b What phase is the water in at B? How can you see that?

c Hot water vapour is also often called steam.
Where is the water present as steam, at A or at B? Explain your answer.

figure 8 What phases is the water in?

5 Fog or mist consists of small droplets of liquid water.
What makes you notice that when you are walking or cycling through thick mist?

6 The photo in figure 9 was taken shortly after a shower of freezing rain. The freezing rain has created a transparent layer on a branch.

a What phase was the water in when it hit the branch? How can you see that?

b What phase was the water in when the photo was taken? How can you see that?

figure 9 A close-up of a layer of frozen rain on a branch.

7 Fuels can be in solid, liquid or gaseous form.
Give an example from everyday life of:
a a solid fuel.
b a liquid fuel.
c a gaseous fuel.

★ 8 Use the particle model to explain why:
a it is easy to compress a gas but not to compress a liquid.
b a crystal can only be split neatly into two (cleaved) in particular directions.
c you soon smell everywhere in the classroom that a gas tap is open.

★ 9 A liquid does not have a fixed shape because the molecules keep moving past each other in all kinds of directions. A liquid does have a fixed volume, though, because the molecules remain as close to each other as possible.
a Think up an experiment that lets you show that a liquid does not have a fixed shape.
b Think of an experiment to let you show that a liquid has a fixed volume.

Test what you know with *Test yourself*.

EXTRA COHESION AND ADHESION

10 What is the name for the attractive force:
a between molecules of the same substance? *adhesion / cohesion*
b between the molecules of different substances? *adhesion / cohesion*

11 Use the concepts of cohesion and adhesion to explain:
a why a drop of water hanging from a tap takes on a spherical shape (figure 7).
b why the shape of the meniscus (curved surface) of the water in a test tube is concave (figure 10).
c why you can write on a paving stone with a piece of chalk.
d why the shape of the meniscus (curved surface) of mercury in a test tube is convex (figure 10).
e why water drops roll off the feathers of a duck without wetting them.

figure 10 The surface of the water (left) has a concave meniscus, whereas the mercury (right) has a convex meniscus.

2 Temperature

LEARNING OBJECTIVES

3.2.1 You can describe how you can measure the temperature of the air around you.
3.2.2 You can list the parts of a liquid thermometer.
3.2.3 You can explain how a liquid thermometer works.
3.2.4 You can describe a digital thermometer.
3.2.5 You can explain what the measurement range of a digital thermometer is.
3.2.6 You can give a thermometer a graduated scale in degrees Celsius using the melting point of ice and the boiling point of water.
EXTRA 3.2.7 You can explain why and how the body temperatures of passengers are measured quickly at an airport.

TAXONOMY	LEARNING OBJECTIVES AND EXERCISES						
	3.2.1	3.2.2	3.2.3	3.2.4	3.2.5	3.2.6	3.2.7
Remembering		1		3d			9a
Understanding			3ac, 5bc		3b, 7abc	2	8ac
Using					7d	4	9bc
Analysing	6abc		5a				8b

The weather forecast warns us about slippery conditions if temperatures 'below zero' are expected. Wet parts of the roads can then freeze, creating an extremely slippery layer of 'black ice' on the road surface. When the temperature of the air outside rises above zero, it will thaw and the slippery conditions will disappear again. A weather thermometer lets you check whether the predictions in the weather forecast were correct or not.

MEASURING THE TEMPERATURE

Your perceptions of heat and cold are not terribly reliable. Luke-warm water can feel hot if your fingers are cold. When it is windy in the winter, it seems colder than it actually is: the more wind there is, the colder it feels - even if the temperature stays the same.

A **thermometer** lets you measure the temperature of the air around you. This gives you a numeric value for the temperature that is independent of your own perceptions. You might think it's "bitterly cold" when somebody else just says it's "nice and fresh". But if you have a thermometer that is working properly, you will both get the same value for temperature.

If you hang a thermometer up in the sun, it will show a temperature that is higher than the outside air (just as your skin also warms up if you sit in the sun – you only notice that the air is not so warm after all when a cloud goes in front of the sun). A thermometer that is hung up in the sun can therefore not give the right value for the air temperature.

That is why meteorologists hang their thermometers up 1.5 m above the ground, in a cabinet that has been painted white. The walls of one of these weather station 'huts' have openings that the wind can blow through freely (figure 1). The thermometers in the weather station are at the same temperature as the air flowing past them. This gives a reliable measurement of the temperature.

figure 1 A meteorologist reading the temperature.

THE LIQUID THERMOMETER

One well-known type of thermometer is the **liquid thermometer.** This type of thermometer consists of a **reservoir** and a **riser capillary** with a graduated scale alongside (figure 2). The reservoir and part of the riser capillary are filled with a liquid. Almost all thermometers use alcohol, with a dye added to make it easier to see.

When the temperature increases, the liquid in the reservoir expands. That pushes the level of the liquid in the capillary tube up. When the temperature decreases, the liquid contracts again and the liquid level falls. Because the capillary tube is very narrow, you can see the liquid rise or fall with just small temperature differences.

You read off the temperature by comparing the height of the liquid against the graduated scale on the riser capillary. In daily life, thermometers are used with graduated scales marked in degrees Celsius (°C). This graduation is also known as the centigrade scale.

The difference between the highest and lowest temperatures that you can measure with a thermometer is known as the **measurement range** of the thermometer. The measurement range of the thermometer in figure 2 is from –20 to 120 °C.

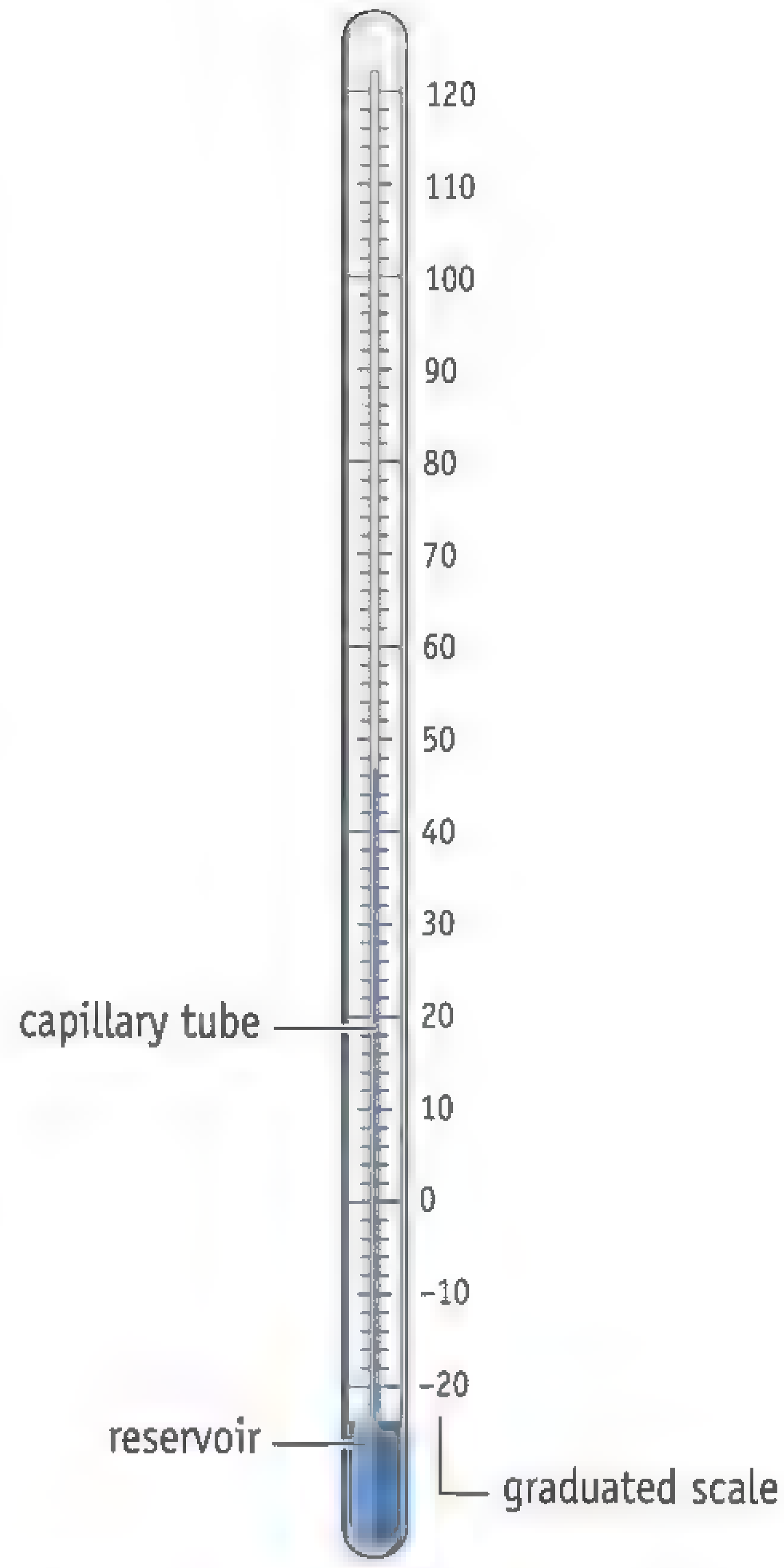


figure 2 A liquid thermometer.

THE CELSIUS SCALE

EXP. 1

Figure 3 shows you how you can add a graduated scale in degrees Celsius to a thermometer.

1 Mark the zero point (0 °C) as the level of the liquid in the thermometer at the temperature of melting ice.
2 Mark the hundred point (100 °C) as the level of the liquid in the thermometer at the temperature of boiling water.
3 Add lines to divide the distance between these points into ten equal parts. Each of these lines then represents a difference of 10 °C.
4 Finally, add more lines with the same spacing between them below the zero point and above the hundred point.

It is simply a question of everyone agreeing that the melting point of water is exactly 0 °C and the boiling point of water is exactly 100 °C.

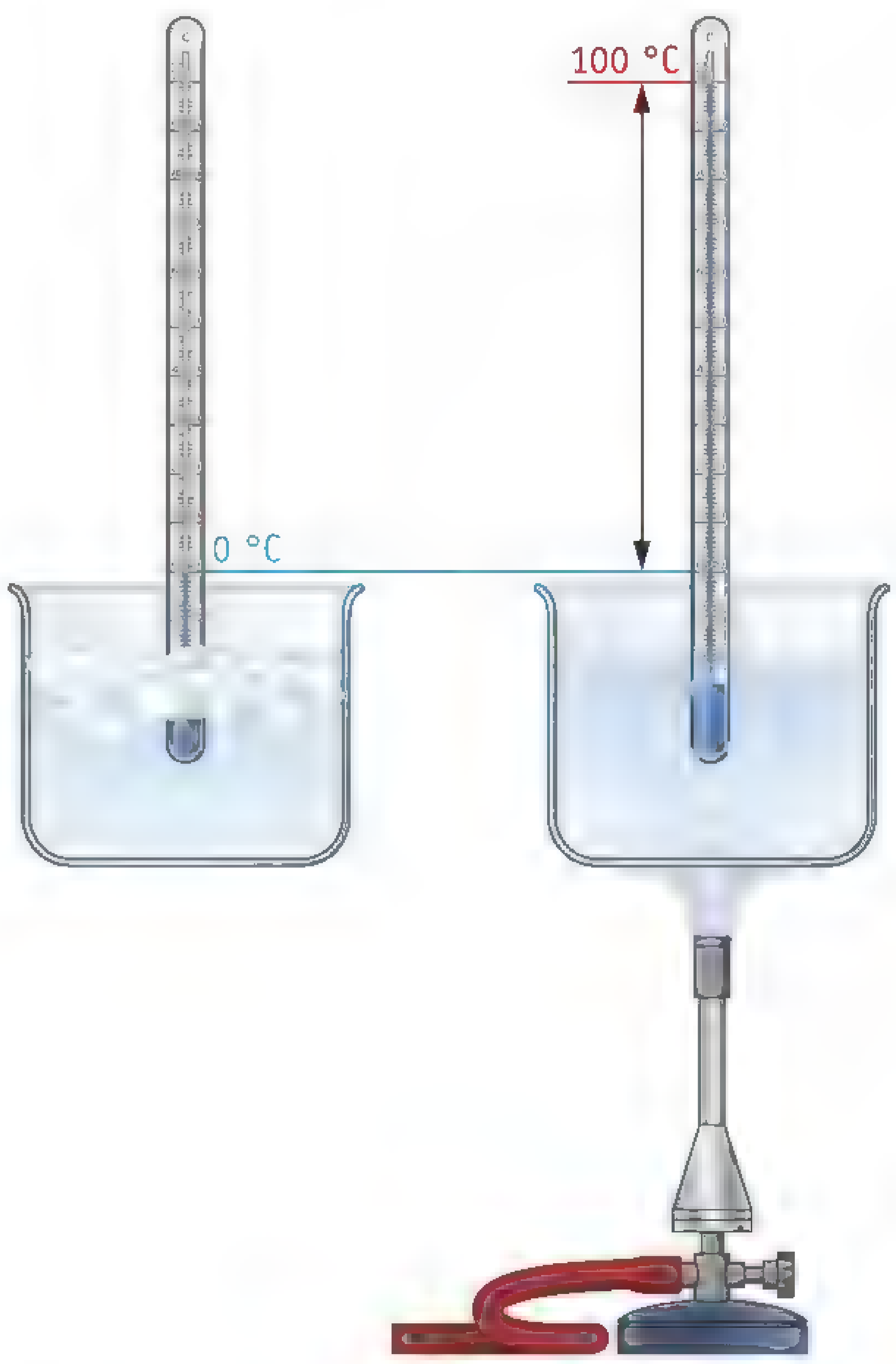


figure 3 Making a graduated scale for temperature.

DIGITAL THERMOMETERS

Special liquid thermometers were used in the past for measuring your body temperature. The measurement range of one of these clinical thermometers is 35 °C tot 43 °C. The riser capillary is narrower and the reservoir larger than in normal liquid thermometers. That is why there is so much space between the degree markings, letting you read the temperature easily to an accuracy of a tenth of a degree.

Nowadays, **digital thermometers** are often used as clinical thermometers. That type of thermometer shows the temperature in numbers on a small screen. This lets you see at a glance what your body temperature is (figure 4). A digital thermometer does not contain a liquid that expands and contracts as the temperature rises or falls. Instead, it works electronically.

figure 4 A digital ear thermometer.

Practice the concepts using the *Flash cards*.

EXTRA MEASURING TEMPERATURES AT AIRPORTS

You are not allowed to travel if you have a severe infectious disease. That stops you from infecting other people who would then become sick. In 2020, millions of people worldwide were infected by coronavirus and there were lots of deaths as a result. People who were infected with coronavirus were then no longer allowed to fly. Most people ran a high temperature when they had the coronavirus: their body temperature was then above 38 °C.

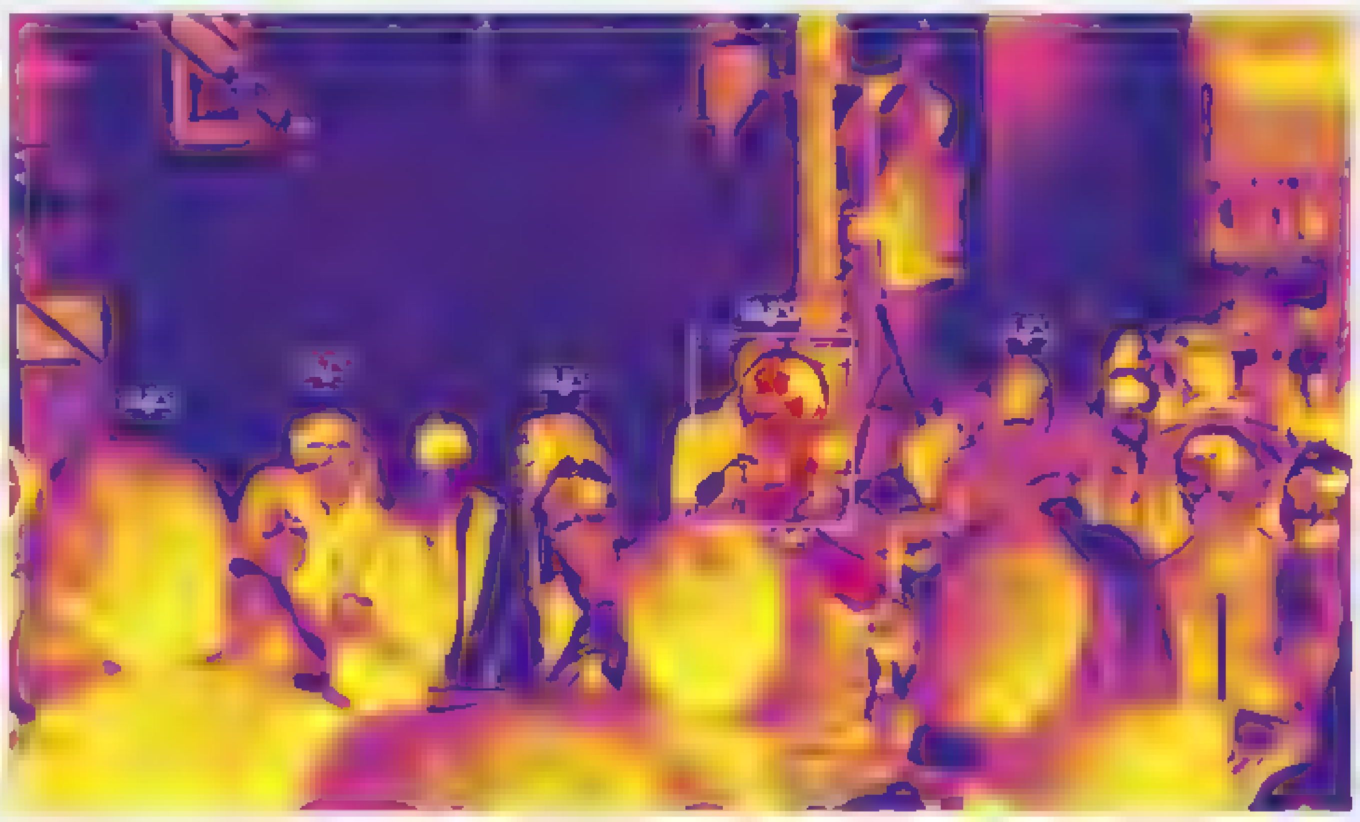


figure 5 Thermogram of a group of people.

That's why passengers' temperatures are measured at airports. To make it possible to measure lots of people's temperatures in a short time, infrared thermometers are used. Every human being gives off thermal radiation. You can't see that radiated heat with the naked eye, but an infrared thermometer is able to detect it. The higher the body temperature, the more thermal radiation the body emits.

An infrared camera can make a thermogram (figure 5), a picture in which various temperatures are shown in different colours. Looking at the colours in a thermogram lets you determine the temperature. If someone has a fever, they aren't allowed to get on the plane or go to another country.

COURSE MATERIAL

1 What two components make a liquid thermometer?

2 Describe in your own words how you can calibrate a thermometer with a graduated scale in degrees Celsius.

IN PRACTICE

3 Figure 6 shows four different thermometers.

a Read off each thermometer as accurately as possible.

thermometer a: .... °C

thermometer b: .... °C

thermometer c: .... °C

thermometer d: .... °C

b Put the thermometers in sequence according to how accurate they are. Put the most accurate one first.

....

c Which of the thermometers show the temperature using a substance that can expand and contract?

....

d What is the name for a thermometer like (b) that is easy to read?

a .... thermometer

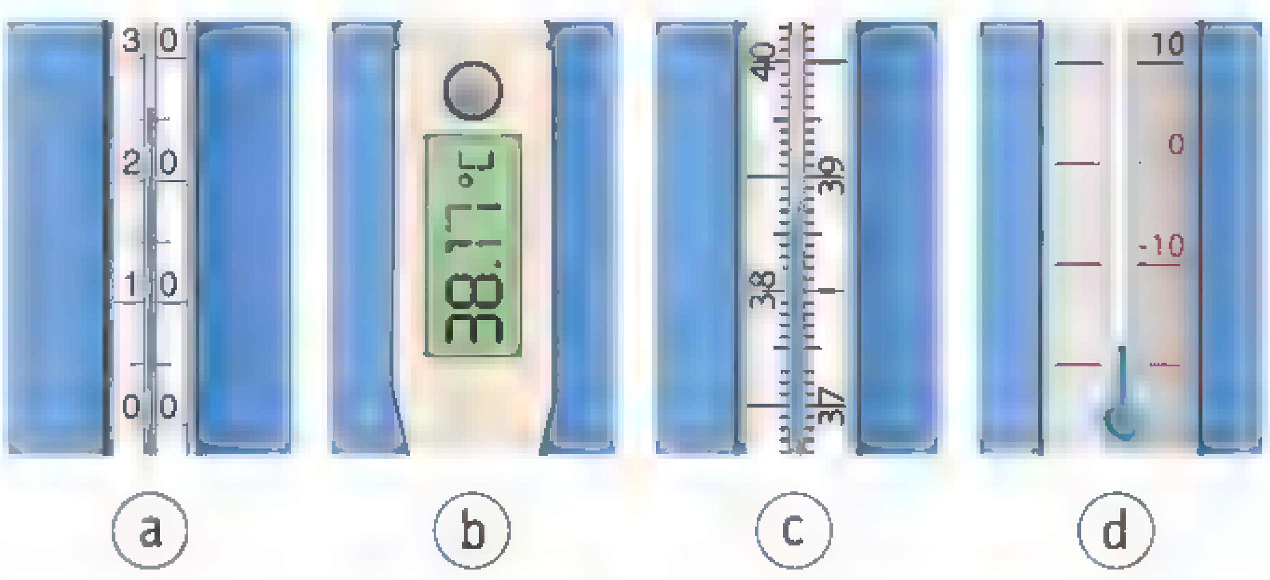


figure 6 Four thermometers.

4 Emma has done an experiment using a liquid thermometer that has no graduated scale. She has marked the zero point and the hundred point (figure 7).
Determine the temperature the thermometer is currently showing as accurately as possible. Tip: make a graduated scale.

figure 7 A thermometer without a graduated scale.

5 Two of the things that affect the accuracy of a liquid thermometer are the diameter of the capillary tube and the size of the liquid reservoir.
Compare the following four thermometers:

- Thermometer A has a large liquid reservoir and a wide capillary tube.
- Thermometer B has a small liquid reservoir and a wide capillary tube.
- Thermometer C has a large liquid reservoir and a narrow capillary tube.
- Thermometer D has a small liquid reservoir and a narrow capillary tube.

a Explain which thermometer would be the best one to use if you want to measure small temperature changes.
b What is the benefit of having a greater distance between the degree markers?
c What are the disadvantages of having a greater distance between the degree markers?

6 In the mountains, you can sometimes sunbathe in your swimsuit although your deckchair is standing in the snow (figure 8).
a How can you tell that the air temperature is still less than 0 °C?
b How can you tell that the temperature of your skin is a long way above 0 °C?
c Suppose that there was a thermometer in the sun next to your deckchair. Would the thermometer give a reliable value for the air temperature? Explain your answer.

figure 8 Sunbathing in the snow.

7 Car engines are cooled using a coolant liquid. You can see the temperature of the coolant on the dashboard (figure 9).
a How many sections is the temperature scale divided into?
b What do the 'Hi' and 'Lo' indications mean?
c Where will the needle point when the engine has just been started up?
d Why is this temperature scale more useful for a car driver than a scale marked in degrees Celsius? Explain your answer.

figure 9 The temperature scale for a car engine.

Test what you know with *Test yourself*.

EXTRA MEASURING TEMPERATURES AT AIRPORTS

8 An ear thermometer is a lot more accurate than an infrared imaging thermometer.

a Why are passengers' temperatures not taken at airports using ear thermometers?
b Why is an infrared thermometer pointed at the passengers' foreheads?
c After their temperature is measured using an infrared thermometer, some passengers need a second measurement to be taken using an ear thermometer.
Why is that done?

9 Figure 10 shows you a thermogram of a passenger.

a Which part of the body is at the lowest temperature?
b Why is the temperature of that part of the body lowest?
c The forehead is one of the areas where the temperature is high.
Why might that be the case?

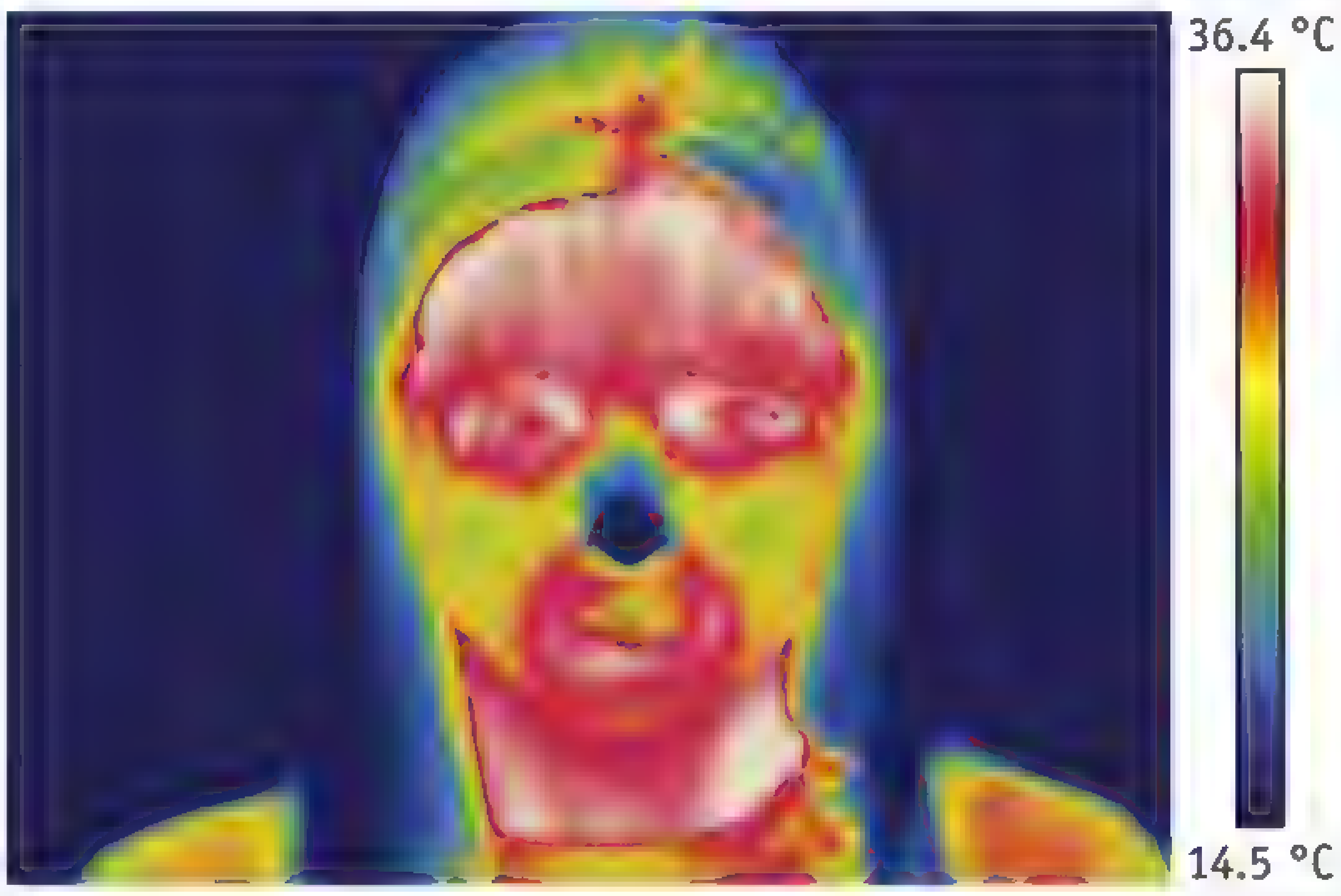


figure 10 Thermogram of a passenger.

3 Phase changes

LEARNING OBJECTIVES

3.3.1 You can name the six phase changes that substances can undergo.

3.3.2 You can describe how the phase transitions of water play a key role in all kinds of weather phenomena.

3.3.3 You can use the particle model to explain why temperature plays a key role in melting and evaporation.

EXTRA 3.3.4 You can explain why water contracts as it cools down to 4 °C and then expands again as it cools further from 4 °C to 0 °C.

TAXONOMY	LEARNING OBJECTIVES AND EXERCISES			
	3.3.1	3.3.2	3.3.3	3.3.4
Remembering	2ab	1abcde		
Understanding	4acdefghi, 6c	6b, 7ab, 8a	3, 9a	11b
Using	5	6a, 8b	9c	11a, 12ab, 13
Analysing			9b, 10	

The weather can change suddenly. A summer's day can begin with a clear blue sky and end with a heavy thunderstorm. After a cold night in the winter, trees and shrubs can suddenly be coated with a thick layer of frost. When a thaw sets in, the ice that people were skating on the day before soon becomes unreliable. All these situations involve water changing phases.

PHASE TRANSITIONS

When water melts or freezes, this is known as a **phase transition**: the substance changes from one phase to another.

There are six phase transitions (figure 1):

- **solidification**: from liquid to solid;
- **melting**: from solid to liquid;
- **evaporation**: from liquid to gas;
- **condensation**: from gas to liquid;
- **deposition**: from gas to solid;
- **sublimation**: from solid to gas.

figure 1 A diagram of the phase transitions.

There are two common words for the transition from liquid to solid: **freezing** and solidifying. You say water 'freezes', but if you were talking about candle wax, you would say it 'solidifies'. The word generally used depends on the temperature. A liquid that becomes solid at temperatures of 0 °C or lower is said to 'freeze'. If the same thing happens at a higher temperature, the word 'solidify' is used.

PHASE TRANSITIONS AND THE WEATHER

The phase transitions of water play an important role in all sorts of weather phenomena.

FREEZING

When it is freezing, a layer of ice appears on the water in puddles and ponds. The topmost layer of the water freezes: it changes from liquid to solid. If the temperatures stay below zero, the layer of ice will thicken from the bottom.

MELTING

When a thaw sets in, the layer of ice on puddles and ponds soon disappears. Tree branches that had been white with frost become bare again, and the droplets of water fall to the ground. Solid ice becomes liquid water.

EVAPORATION

When the sun shines after a shower, the road surfaces soon dry out again. Puddles can become smaller and finally disappear altogether. This happens because the rainwater rapidly evaporates in warm weather: the visible water becomes invisible water vapour.

CONDENSATION

When warm air cools down at night and meets a cold object, the water vapour in the air condenses out of it. Small droplets of water then appear on blades of grass and leaves (figure 2). Invisible water vapour becomes visible water.

figure 2 Dew is made up of small water droplets.

DEPOSITION

If the temperature at night drops to below 0 °C, frost rather than dew is deposited. The water vapour in the air changes to small ice crystals that give a splendid white appearance to tree branches and blades of grass (figure 3).

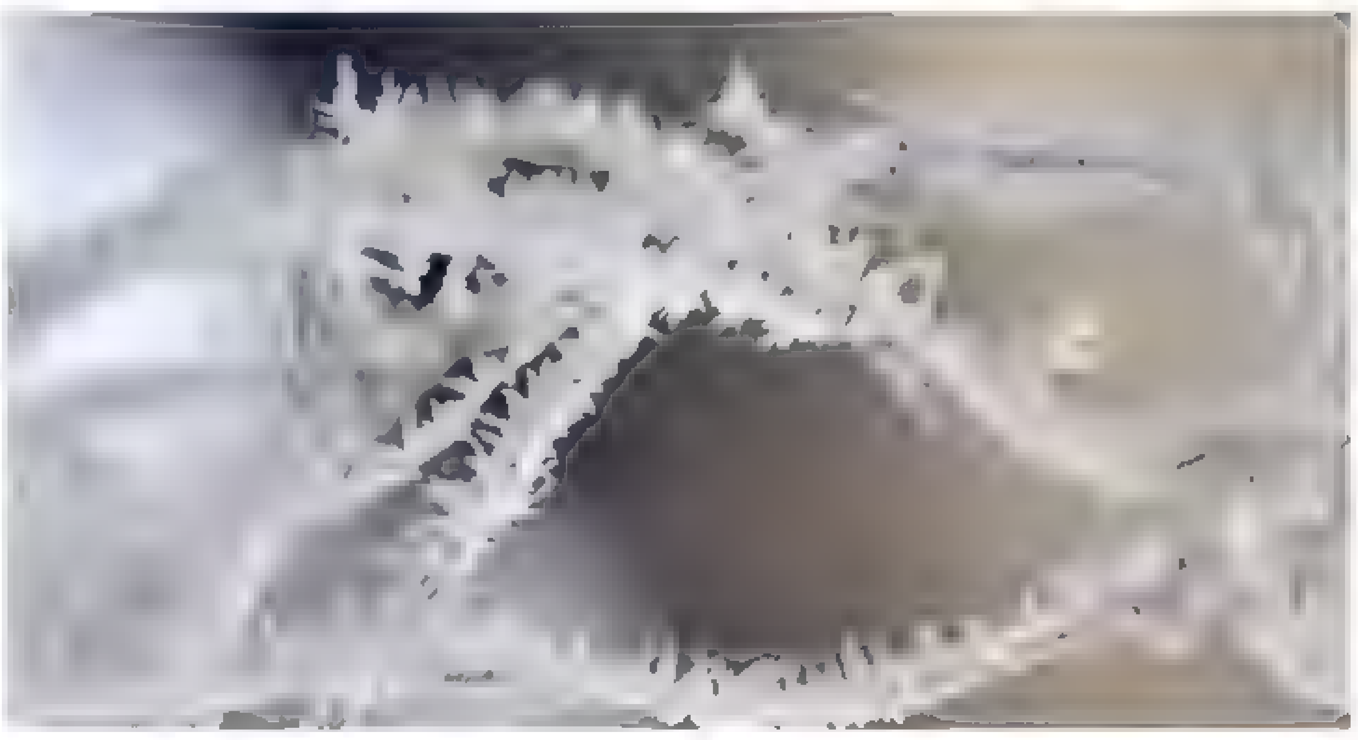


figure 3 Frost on a twig of a tree.

SUBLIMATION

If the air is very cold and dry, a layer of snow will gradually get thinner. This is because ice slowly changes into water vapour under those conditions. There are also substances that sublime rapidly, such as solid carbon dioxide ('dry ice'). This process is called 'sublimation'.

THE INFLUENCE OF TEMPERATURE

Temperature clearly plays a key role in the various phase transitions. The particle model lets you explain why. The phase transitions of melting and evaporation are discussed below as examples.

MELTING IN THE PARTICLE MODEL

In a solid substance, the molecules are stacked closely together in a regular pattern. There are attractive forces between adjacent molecules (ones that are next to each other). This makes sure that every molecule stays in its fixed position. The smaller the distance between two adjacent molecules, the greater the attractive force between them.

When the temperature increases, the molecules will vibrate increasingly vigorously. The distances between the molecules then become greater, as you can see from the fact that the substance expands. The greater distances mean that the attraction between the molecules becomes weaker. When the temperature reaches a certain value (0 °C in the case of water), the attractive force is too weak to hold the molecules fixed in place: the substance then melts and becomes liquid. The molecules can now move back and forth past one another in any direction.

EVAPORATION IN THE PARTICLE MODEL

The molecules in a liquid are constantly in motion. The attractive forces between them ensure that they remain close together. The situation at the liquid surface is different, though. Now and again, a molecule there may have enough speed to escape from the liquid (figure 4). A molecule that does that will then become part of the air above the liquid. Little by little, the liquid loses more and more molecules: the liquid evaporates.

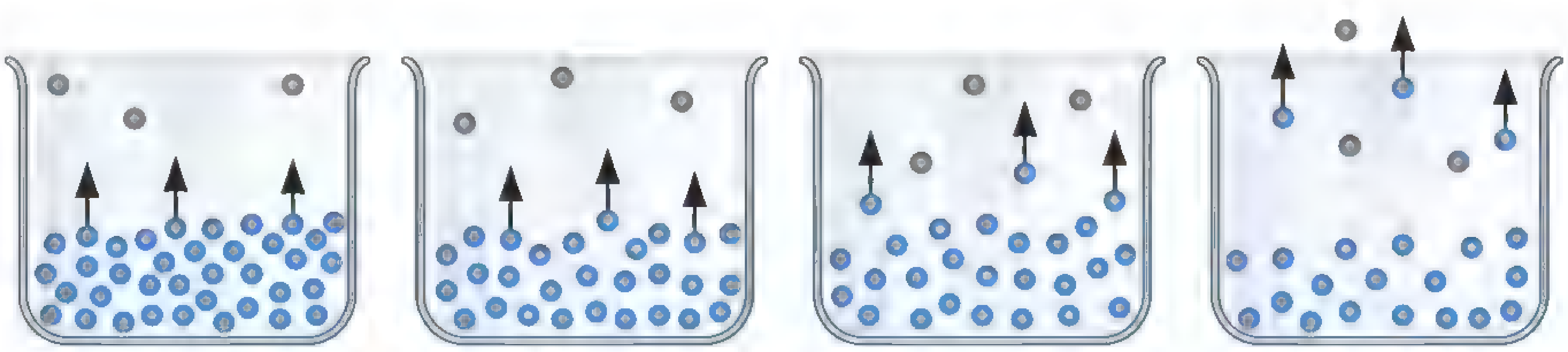


figure 4 Evaporation occurs when molecules escape from a liquid.

The higher the temperature, the greater the average speed of the molecules and the more easily they can escape from the liquid. Liquids therefore evaporate more quickly as the temperature increases.

Practice the concepts using the *Flash cards*.

EXTRA WATER: AN EXCEPTION

Almost all liquids contract as the temperature decreases. Because the molecules are moving more slowly, they collide less vigorously and push each other away less. However, there is one important exception to this rule: water between 4 °C and 0 °C. When water cools down, it contracts like any other liquid until the temperature decreases to 4 °C. But when water cools beyond that, from 4 °C to 0 °C, it actually starts expanding again (figure 5).

If the water then freezes, it expands further: when 1 dm^3 of water freezes at 0 °C, it makes about 1.1 dm^3 of ice. The volume therefore increases by about 10% as water freezes. This is why you have to be very careful that the water in water pipes does not freeze in the winter. Pipes can easily burst as they freeze.

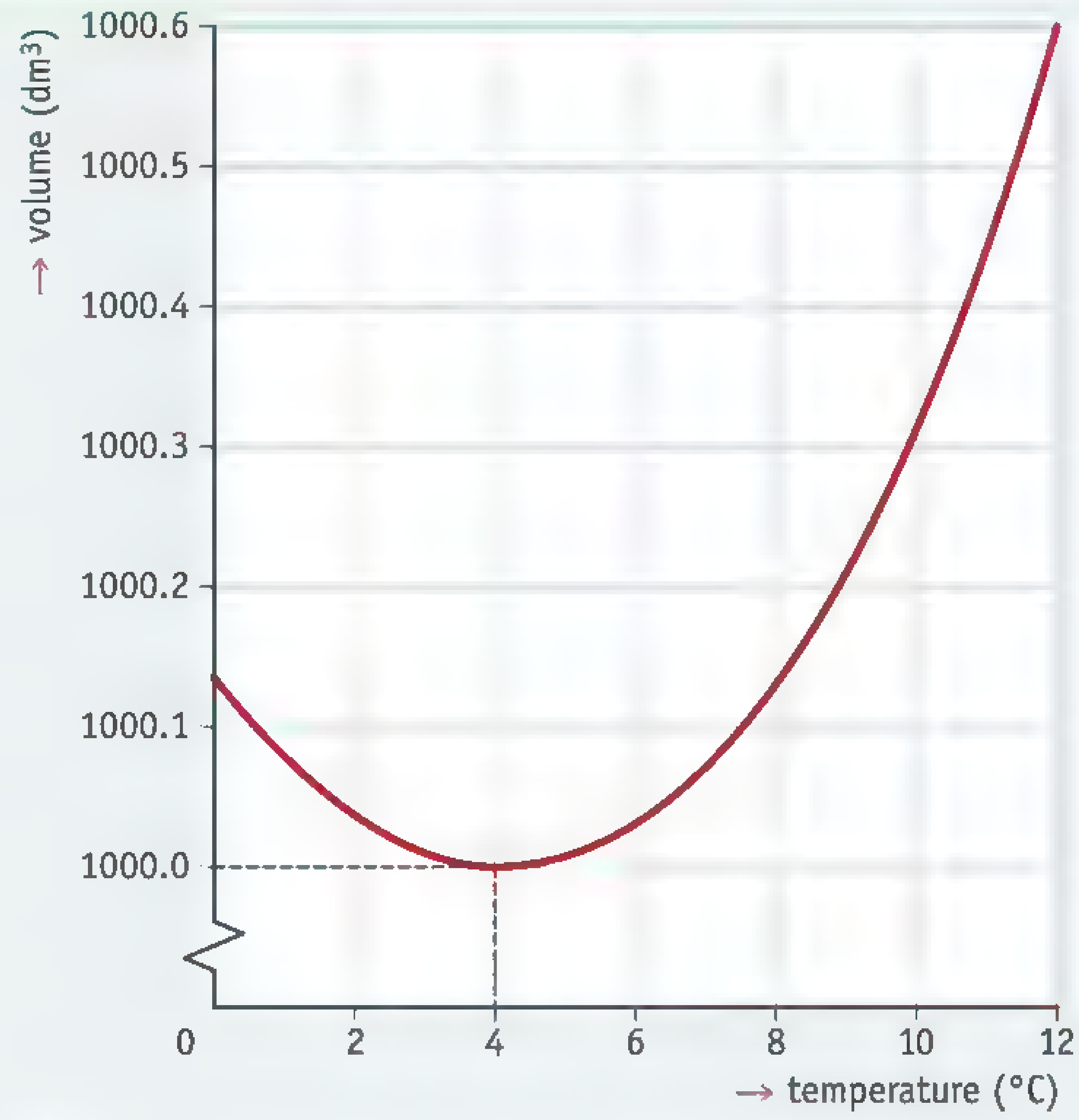


figure 5 The contraction and expansion of water.

The reason why water expands as it freezes is the unusual crystal structure of ice. The molecules form hexagons with a lot of free space between them (figure 6). This means that the average distance between the molecules is greater in ice than it is in water. The hexagons already start forming once the water temperature falls below 4 °C, although no permanent crystal lattice is yet formed. This is why water is at its maximum density at 4 °C.

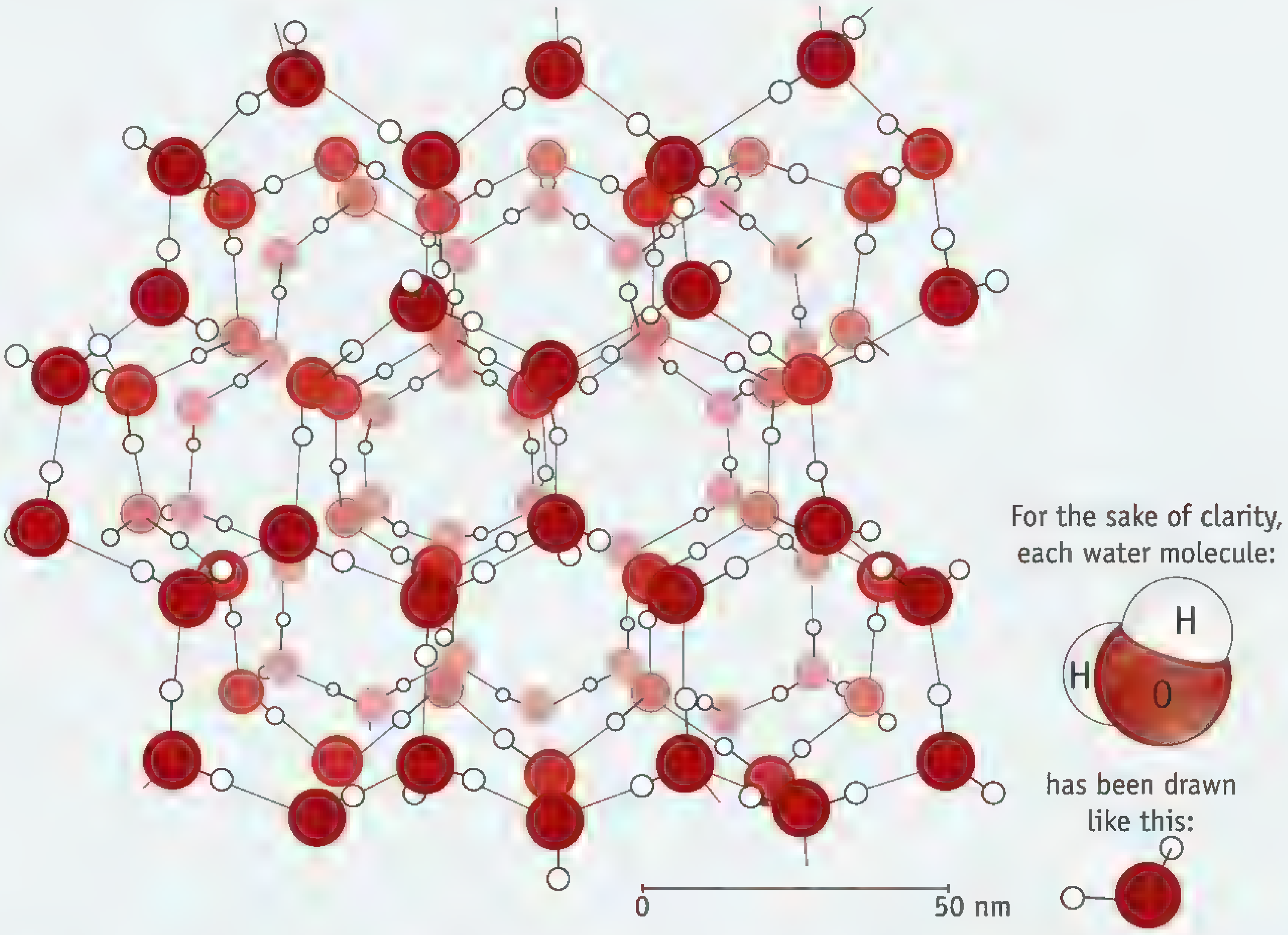


figure 6 Ice has an unusual crystal structure, with a lot of empty space between the molecules.

COURSE MATERIAL

1

Which phase transition is the reason why:

a grass is wet with dew in the morning?
freezing / condensation / deposition / melting / evaporation / sublimation

b a road dries out again quickly after a shower of rain?
freezing / condensation / deposition / melting / evaporation / sublimation

c the branches of trees and shrubs get covered with a white layer, although it hasn't snowed?
freezing / condensation / deposition / melting / evaporation / sublimation

d a layer of snow gets thinner and thinner even if the temperature stays below zero?
freezing / condensation / deposition / melting / evaporation / sublimation

e you can see a cloud of mist coming out of your mouth when the weather is cold?
freezing / condensation / deposition / melting / evaporation / sublimation

2

This exercise is about the words 'solidify' and 'freeze'.

a Explain the similarity between the meanings of these words.

b Explain the difference between the meanings of these words.

3

If you hold an ice cube in your hand, the ice melts.
Describe what is happening to the water molecules then.

IN PRACTICE

4

Which phase transition is involved:

a when your clothes dry out again in the wind after a shower?
freezing / condensation / deposition / melting / evaporation */ sublimation*

b when water droplets appear on the inside of a car's windows on a cold day?
freezing / condensation / deposition / melting / evaporation / sublimation

c when you make ice cubes in the freezer compartment of the fridge?
freezing / condensation / deposition / melting / evaporation / sublimation

d when you let a bag of ice cubes from the freezer thaw?
freezing / condensation / deposition / melting / evaporation / sublimation

e when the mirror in the bathroom fogs up?
freezing / condensation / deposition / melting / evaporation / sublimation

f when the water in a birdbath slowly disappears?
freezing / condensation / deposition / melting / evaporation / sublimation

g when water appears on the outside of an ice-cold glass of water?
freezing / condensation / deposition / melting / evaporation / sublimation

h when ice crystals appear on deep-frozen products?
freezing / condensation / deposition / melting / evaporation / sublimation

i when you carefully allow potatoes in a pan to boil dry?
freezing / condensation / deposition / melting / evaporation / sublimation

5

Even when it is freezing outside, you can still hang wet washing on the line. It will freeze stiff pretty quickly. Even so, you can bring your washing in again the next day and it will be almost dry.
How is it possible for the washing to be nearly dry after 24 hours in the freezing cold?

6

When Brian arrives home and goes inside, the lenses of his glasses fog up straight away.

a What can you say about the temperatures indoors and out?

b Where do the water droplets come from that are misting up Brian's spectacle lenses?

c Which phase transition is involved here?

7

The weather forecast issues a fog warning: “Fog may form throughout the country during the night. This may affect road traffic severely. During the morning, the fog will dissolve.”

a Which phase transition is responsible for the fog occurring?

b Which phase transition is responsible for the fog ‘dissolving’?

8

In the summer, the sun may sometimes start shining again brightly very shortly after a heavy shower of rain. In cases like that, a mist can appear above a road surface (figure 7).

a People will then often say that the road is “steaming”. But are you actually seeing steam? Explain.

b Explain what is causing the mist. Tip: the mist is the result of two phase transitions occurring, one rapidly after the other.

figure 7 Bright sunlight after a heavy shower can make a road ‘steam’ like this.

★ 9

If you put a little bit of ether (a volatile liquid) on a sheet of glass, the ether evaporates quickly.

a Only molecules with relatively high speeds are able to escape from the liquid. Why are molecules travelling at lower speeds unable to escape from the liquid?

b Explain what happens to the average speed of the molecules that remain behind in the liquid.

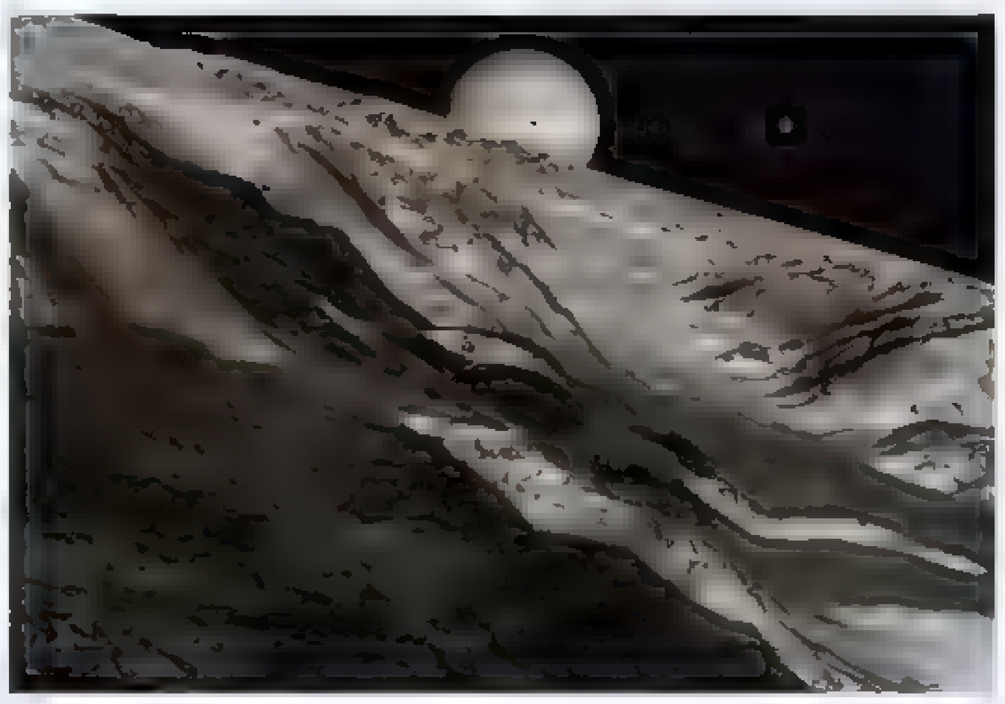
c What does that mean for the temperature of the remaining liquid? Its temperature *falls / stays the same / rises*.

★ 10

At very low temperatures, ice becomes extremely hard (figure 8). Explain this using the particle model.

figure 8 A website about Ganymede (the picture is an artist’s impression).

The largest moon of Jupiter (and indeed in the entire solar system) is called Ganymede. The surface consists primarily of ice. Because it is extremely cold on Ganymede (surface temperatures range from –183 to –113 °C), the ice is incredibly hard. It is much harder than ice you might come across on Earth.



Test what you know with *Test yourself*.

EXTRA WATER: AN EXCEPTION

11 Have a look at figure 5.

a Which liquid has the greater density: water at 0 °C or water at 2 °C? Explain your answer.

b There is another temperature at which water has the same density as at 0 °C. What temperature is that?

12 If a water pipe freezes in the winter, it can burst.

a Explain why this can happen.

b You will only notice that the water pipe is broken when it starts to thaw. Why?

13 Figure 9 shows you two possible temperature distributions for the water in a pond during a period when the weather has been freezing for some time. There is a layer of ice on the water.

Explain which of the water temperature distributions is correct.

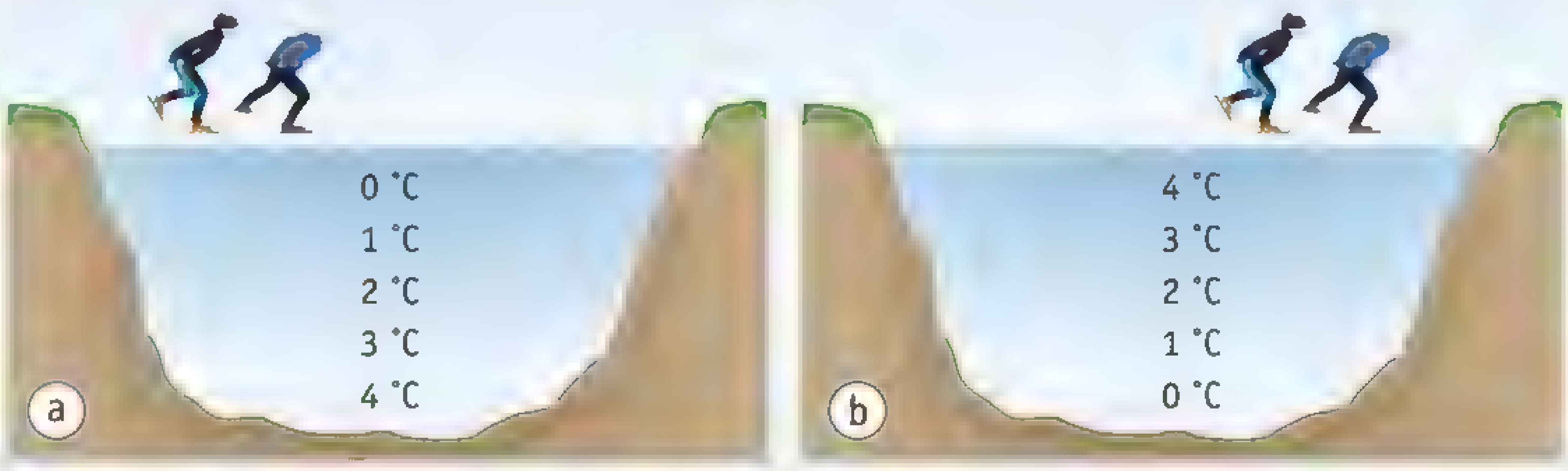


figure 9 Which water temperature distribution is correct – (a) or (b)?

4 Boiling point and melting point

LEARNING OBJECTIVES

3.4.1 You can describe what happens when water boils.

3.4.2 You can describe what the boiling point and melting point (freezing point/ solidification point) of a substance are.

3.4.3 You can explain why the boiling point and melting point are properties of a substance.

3.4.4 You can explain how you can lower the freezing point or melting point of water.

3.4.5 You can interpret the melting, freezing and boiling graphs of a substance in a temperature-time diagram.

EXTRA 3.4.6 You can explain the difference between a boiling point and a boiling curve using a boiling graph in a temperature-time diagram.

TAXONOMY	LEARNING OBJECTIVES AND EXERCISES							
	3.4.1	3.4.2	3.4.3	3.4.4	3.4.5	3.4.6	2.1.2*	3.1.1*
Remembering	2	1ac, 4a		1b, 3				
Understanding			5c, 6b, 10b		5bc, 8abcde	11abc, 12bcdef	6a	
Using	10a	4bc, 6c		7	5a	12a		
Analysing					9ab	11d		10cd

* You can find this learning objective in an earlier section.

The rainwater that falls during a shower disappears very quickly. Some of it is channelled away through the sewers, some is absorbed into the soil and some evaporates. The evaporation process is unspectacular. You don't notice anything at all, other than that the quantity of water slowly decreases.

THE BOILING POINT

If you heat water, tiny air bubbles will appear after a little while. The air that is dissolved in the water is then reappearing. A couple of minutes later, bubbles of water vapour appear in the water. The temperature is then almost 100ºC. These bubbles appear at the bottom and disappear again before reaching the water surface. This can then make a noise: a kettle of water coming to the boil may be said to be 'singing'.

When the temperature has reached 100 ºC, the steam bubbles do reach the water surface. There they pop and the water vapour mixes with the air above the water. That is **boiling**: the water is now evaporating not only at the water surface but throughout the liquid (figure 1).

If you keep on heating it, the water will keep boiling until it has all evaporated. The temperature of the water remains at 100 ºC all that time. This temperature is known as the **boiling point** of water (the word 'point' is used because it is a fixed point on the temperature scale).

Almost every pure substance has its own characteristic boiling point. A few examples are given in table 1. The boiling point is an important property of a substance.

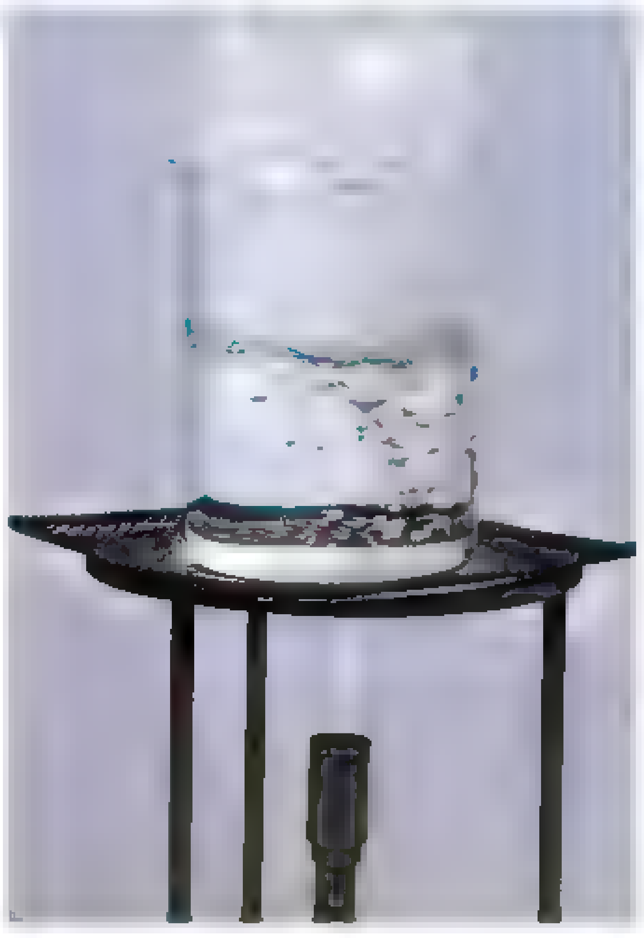


figure 1 When water is boiling, you can see bubbles of steam developing throughout the liquid.

table 1 Melting points and boiling points of various substances.

substance	melting point (°C)	boiling point (°C)
alcohol	−114	78
aluminium	660	2467
butane	−138	−1
glycerol	20	290
gold	1064	2860
iron	1559	2800
mercury	−39	357
lead	328	1740
propane	−188	−42
nitrogen	−210	−196
water	0	100
oxygen	−219	−183

MELTING POINT AND FREEZING POINT

If you put an ice cube tray of water in the freezer compartment, it takes a little while before ice is made. The temperature of the water in the mould must first drop to 0 °C. Only then will the water freeze. The temperature of the water remains at 0 °C until it is entirely frozen.

When you take the ice cubes out of the freezer compartment, they do not start to melt right away either. The temperature of the ice has to rise to 0 °C first. The first melted water will only appear after that temperature has been reached (figure 2).

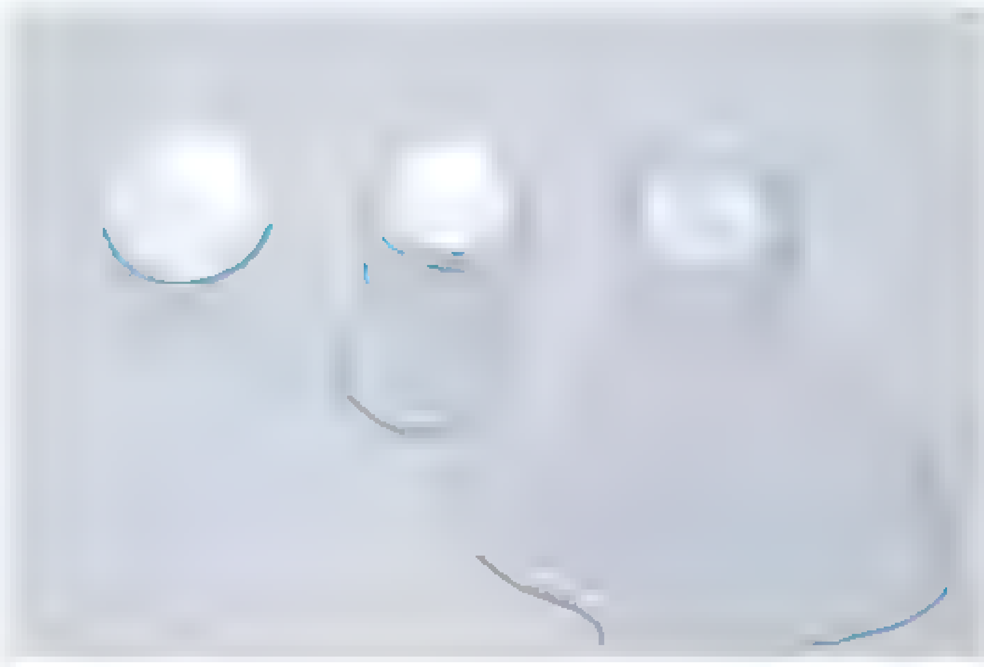


figure 2 An ice cube 1 minute, 5 minutes and 15 minutes after being taken out of the freezer compartment.

Melting ice is therefore at the same temperature as freezing water, 0 °C. This temperature is known as the **melting point** of ice and the **freezing point** of water. Almost every pure substance has its own characteristic melting point (or freezing point, as it is also known). A few examples are given in table 1.

LOWERING THE FREEZING POINT OR MELTING POINT

EXP 5

You can lower the freezing point of water by adding a suitable substance to the water. This is known as 'freezing point depression'. This is done with the coolant water in a car engine, for example. Antifreeze is added to it to prevent it from freezing during the winter. The more antifreeze is added, the lower the freezing point of the mixture becomes.

Salt has the same effect on the freezing point as antifreeze. It is used during the winter to get rid of snow and ice on the roads (figure 3). A mixture of ice and salt has a lower melting point than pure ice. Spreading salt can make snow or ice melt away, even at temperatures below 0 °C. In practice, salting the roads is effective at temperatures down to −8 °C.


figure 3 Spreading salt makes the snow on the road surface melt.

MELTING AND SOLIDIFICATION DIAGRAMS

Figure 4 shows how the melting point of a solid substance can be determined. You heat the substance carefully and measure the temperature at regular intervals. In figure 4, this is being done for stearic acid. This is a substance that is used for a variety of purposes, including making candles (figure 5).

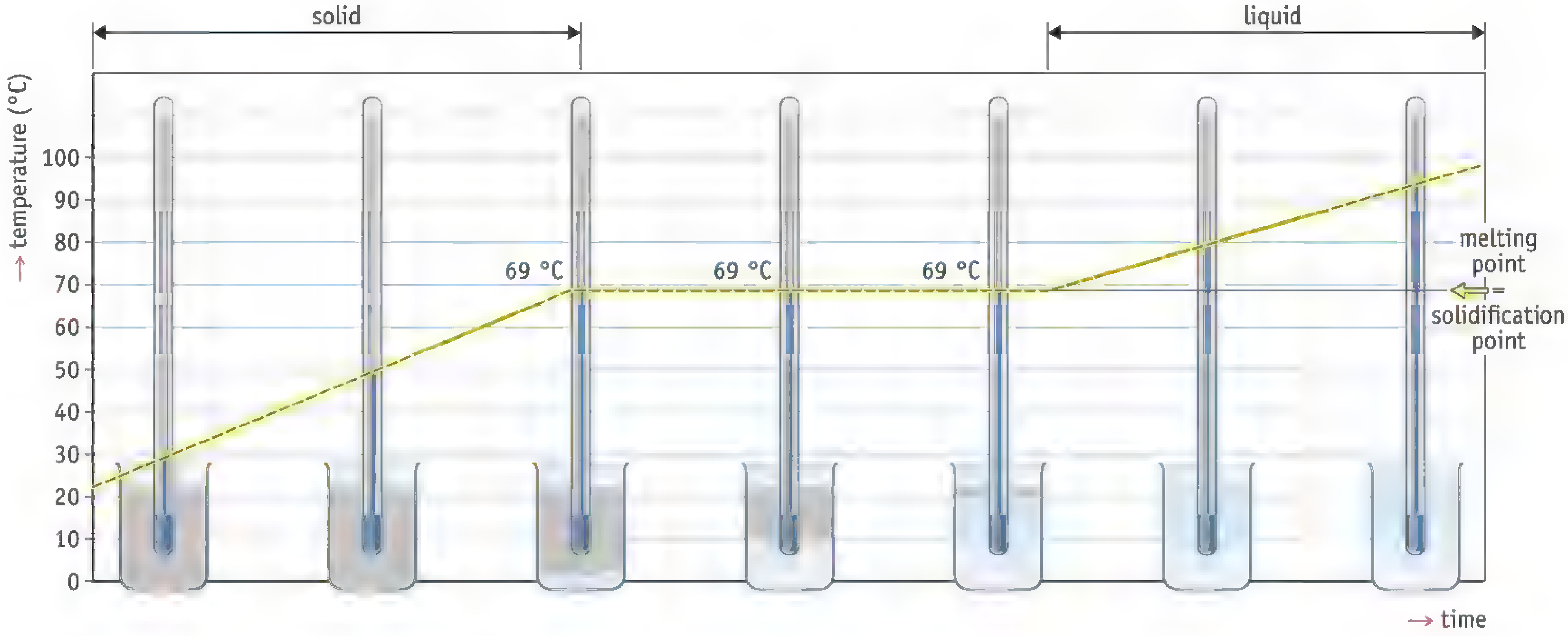


figure 4 The melting diagram of stearic acid.

figure 5 Candles consist largely of stearic acid.

When you heat solid stearic acid, the temperature first increases to 69 °C, the melting point of stearic acid. At that temperature, the stearic acid starts to melt. If you carry on heating, the temperature remains at 69 °C until all the stearic acid has melted. Only then does the temperature start increasing again. Figure 4 shows the way the temperature changes in a **melting diagram**, a graph showing the temperature against time.

If you let liquid stearic acid cool down, the temperature drops to 69 °C again: the solidification point of stearic acid. The temperature remains at 69 °C until the stearic acid has fully solidified. The temperature can then drop further. You can show the way the temperature changes in a **solidification diagram**, a graph showing the temperature against time.

Practice the concepts using the *Flash cards*.

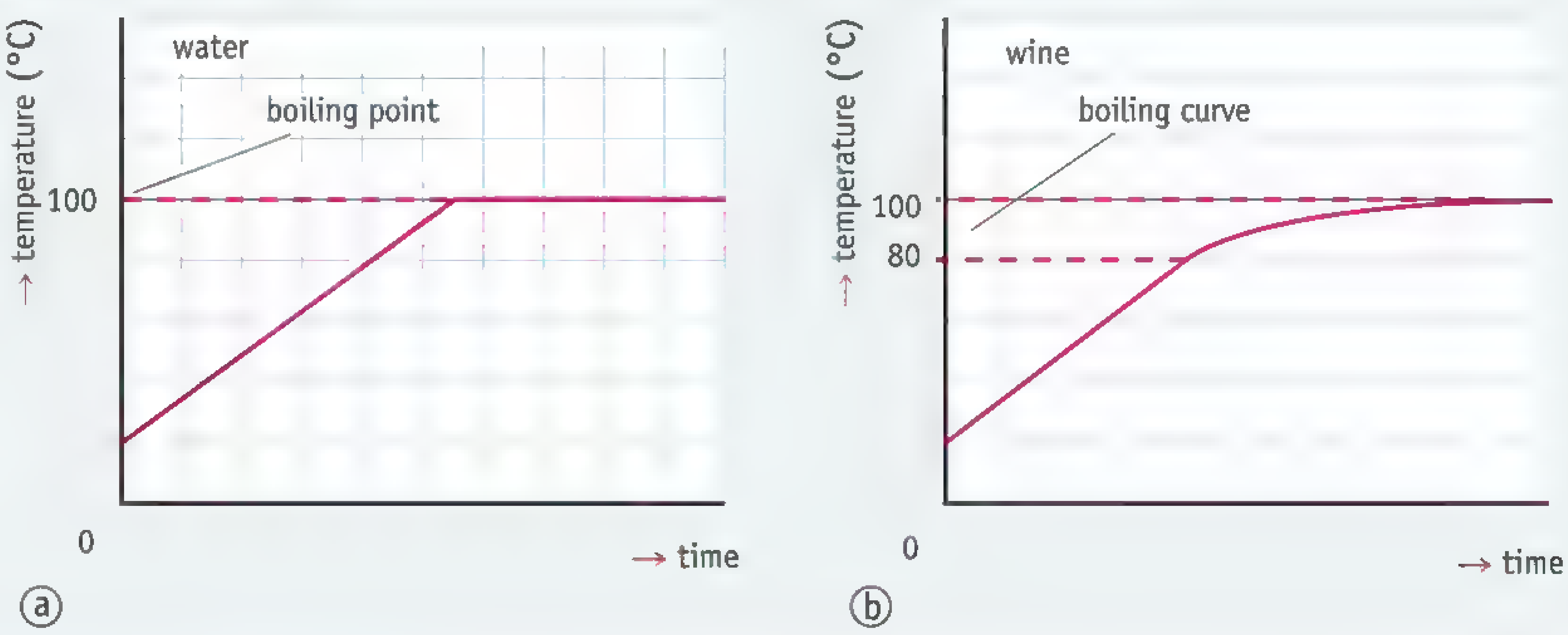
EXTRA THE BOILING CURVE OF A MIXTURE

Wine is a mixture consisting mostly of water and alcohol. The proportion of other substances can be ignored in practice. A bottle of wine contains about 12 per cent alcohol by volume (12% vol.). That means that 100 mL of wine consists of about 12 mL alcohol and 88 mL water.

When you bring wine to the boil, you will notice that it starts to boil at about 80 °C. The temperature then increases slowly to 100 °C (figure 6b). Wine therefore does not have a fixed boiling point in the way that pure water (100 °C) or pure alcohol (78 °C) does. The temperature of the wine does not remain constant while it boils.

What applies for wine is also true for other mixtures of liquids. Mixtures such as these do not have a boiling *point*. Instead, they have a boiling *curve*. The boiling curve of wine goes from 80 to 100 °C.

figure 6 Water has a boiling point (a), whereas wine has a boiling curve (b).



COURSE MATERIAL

1 Almost every pure substance has its own characteristic boiling point, melting point and solidification point.

a Melting ice has a temperature of .... This temperature is known as the .... of water or the .... of ice.

b A mixture of ice and salt has a *lower / higher* melting point than pure ice.

c Boiling water has a temperature of .... This temperature is called the .... of water.

2 Explain why boiling is a special case of evaporation.

3 Explain what antifreeze is and what you do with it. Include the phrase 'freezing point' in your explanation.

IN PRACTICE

4 Soraya is cooking rice. When the water begins to boil, she turns the heat down. The water then keeps simmering gently.

a What is the temperature of the boiling water?
b Will it take any longer for the rice to be ready if you turn the heat down?
c Why is it a good idea to turn the heat down?

5

You need graph paper for this exercise.
Peter is heating a liquid. He records the temperature of the liquid every half minute. His observations are given in table 2.

a Draw the graph of Peter's observations with time on the horizontal axis and temperature on the vertical axis.

See the skills section on *Working with tables and graphs*.

b What is the boiling point of the liquid?

c What liquid might it be?

table 2 Peter's measurements.

time (min)	temperature (°C)
0	20
0.5	33
1.0	46
1.5	58
2.0	68
2.5	75
3.0	77
3.5	78
4.0	78
4.5	78

6

Gallium is a metal that has a silver-white colour. The melting point of gallium is 29 °C and the boiling point is 2205 °C.

a What does the metal gallium look like at room temperature?

b Compare the melting and boiling points of gallium against the melting and boiling points of other substances in table 1.
What is unusual about the melting point and boiling point of gallium?

c You can buy teaspoons made of gallium in joke shops.
What happens if you stir a cup of hot tea with one? Tip: have a look on YouTube.

7

In the winter, salt is sometimes spread on a frozen road surface. The layer of ice then melts. Is the temperature of the melting water then higher than, lower than or equal to 0 °C? Explain your answer.

8

Alice has melted a quantity of stearin. She lets the stearin cool slowly, taking temperature measurements every minute. After the experiment, she makes a graph of her observations (figure 7).

a What is the name for the type of graph that Alice has made?
a *melting curve* / *solidification curve*

b What phase is the stearin in at A?
in the *solid phase* / *liquid phase*

c What phase is the stearin in at C?
in the *solid phase* / *liquid phase*

d Between which two points in time are both liquid and solid stearin present?

e What is the solidification point of the stearin?

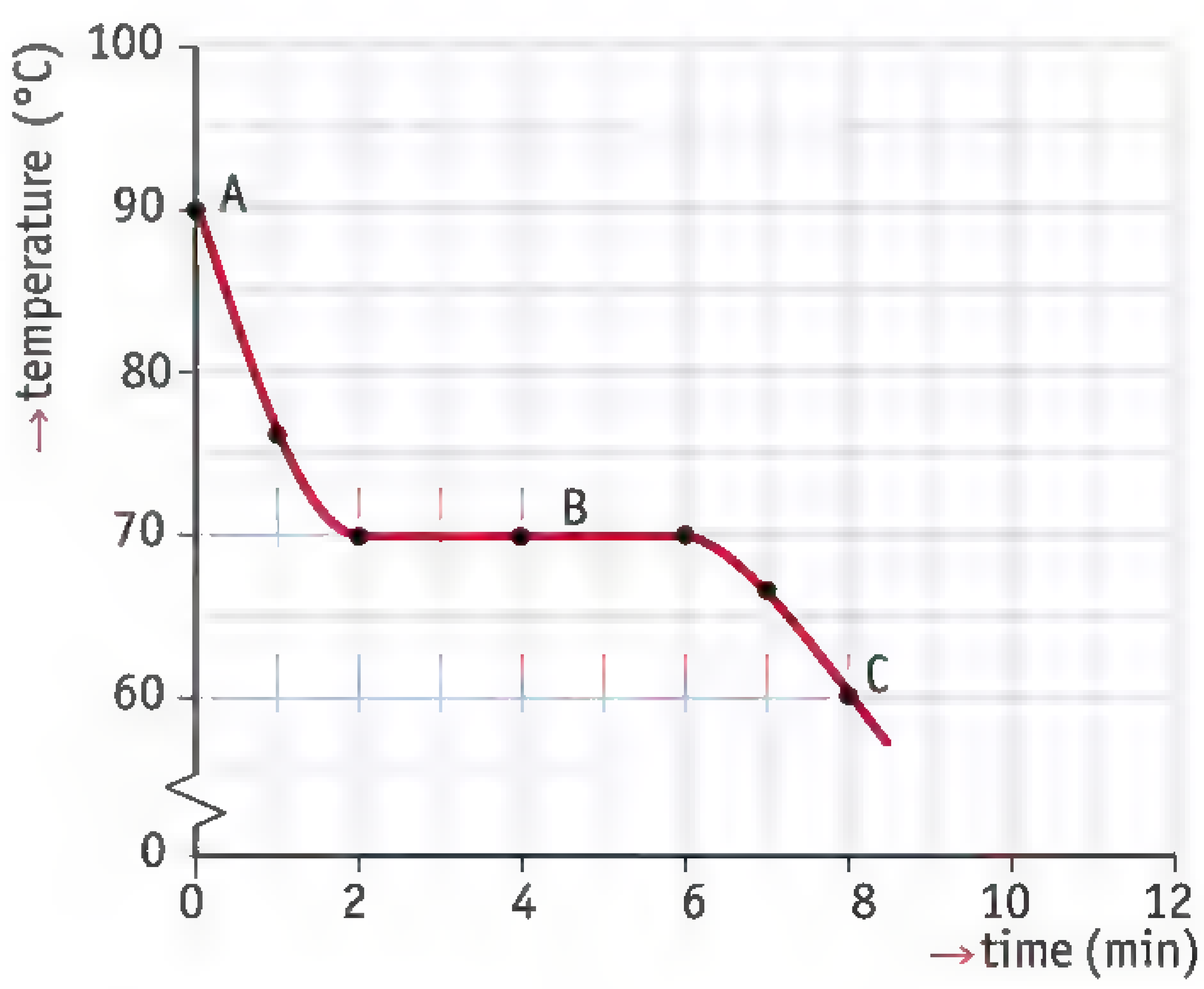


figure 7 Alice's graph.

★ 9

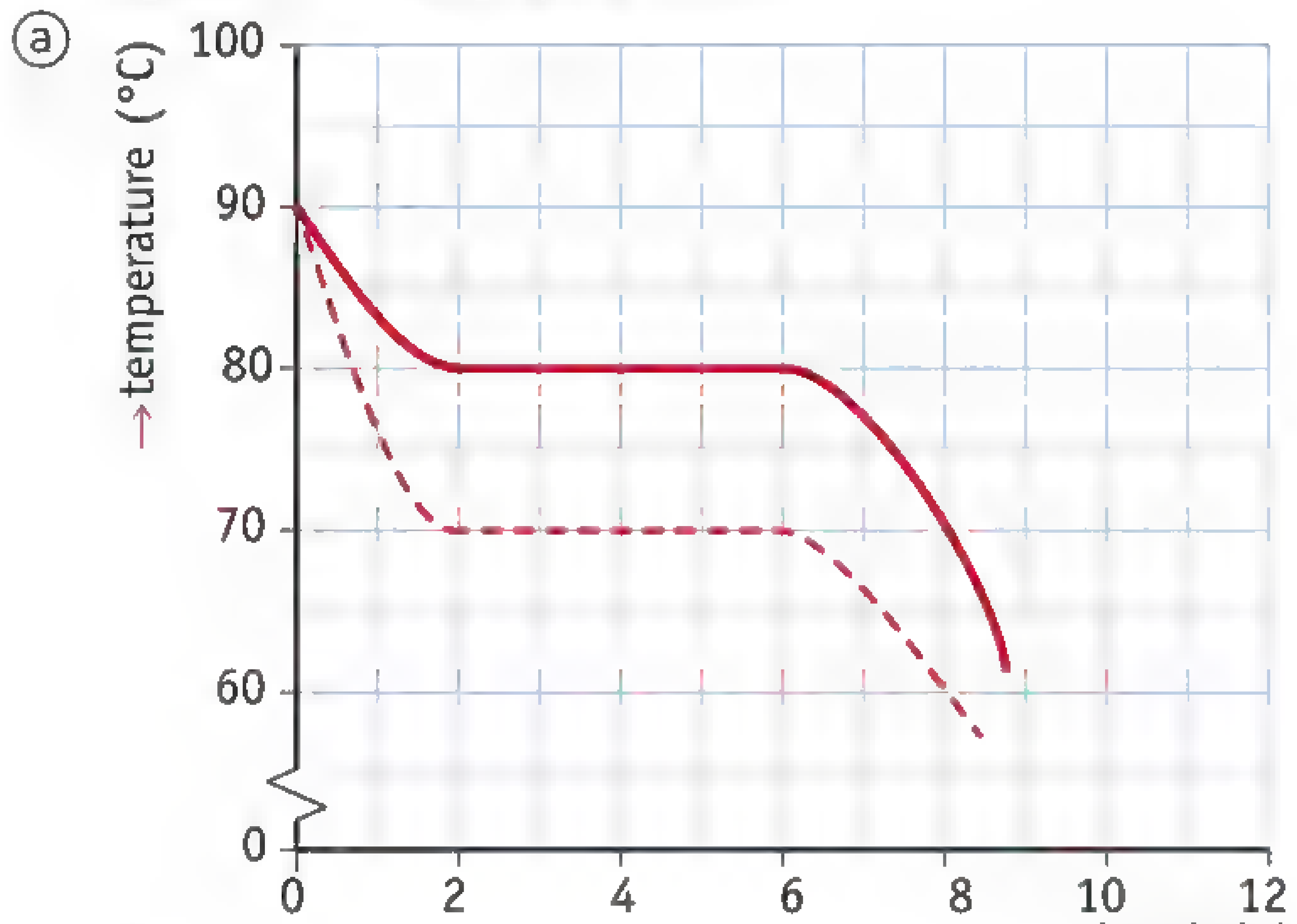
Lakshmi does the same experiment as Alice but uses twice as much stearin. She also makes a graph of her observations.

a Which of the three graphs in figure 8 could be Lakshmi's? Assume that neither Lakshmi nor Alice made any mistakes when carrying out the experiment.

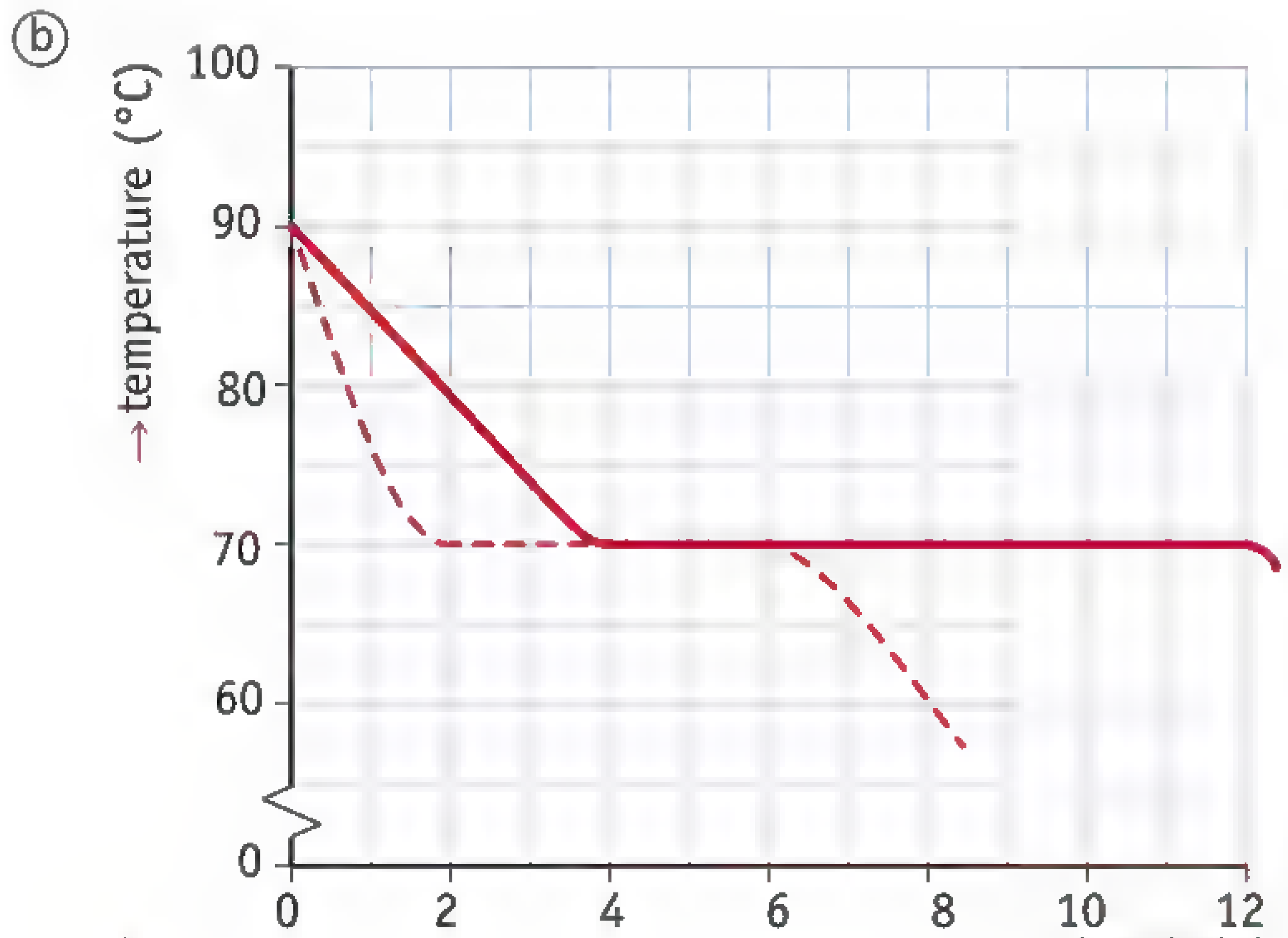
- ○ A graph a
- ○ B graph b
- ○ C graph c

b Explain your choice.

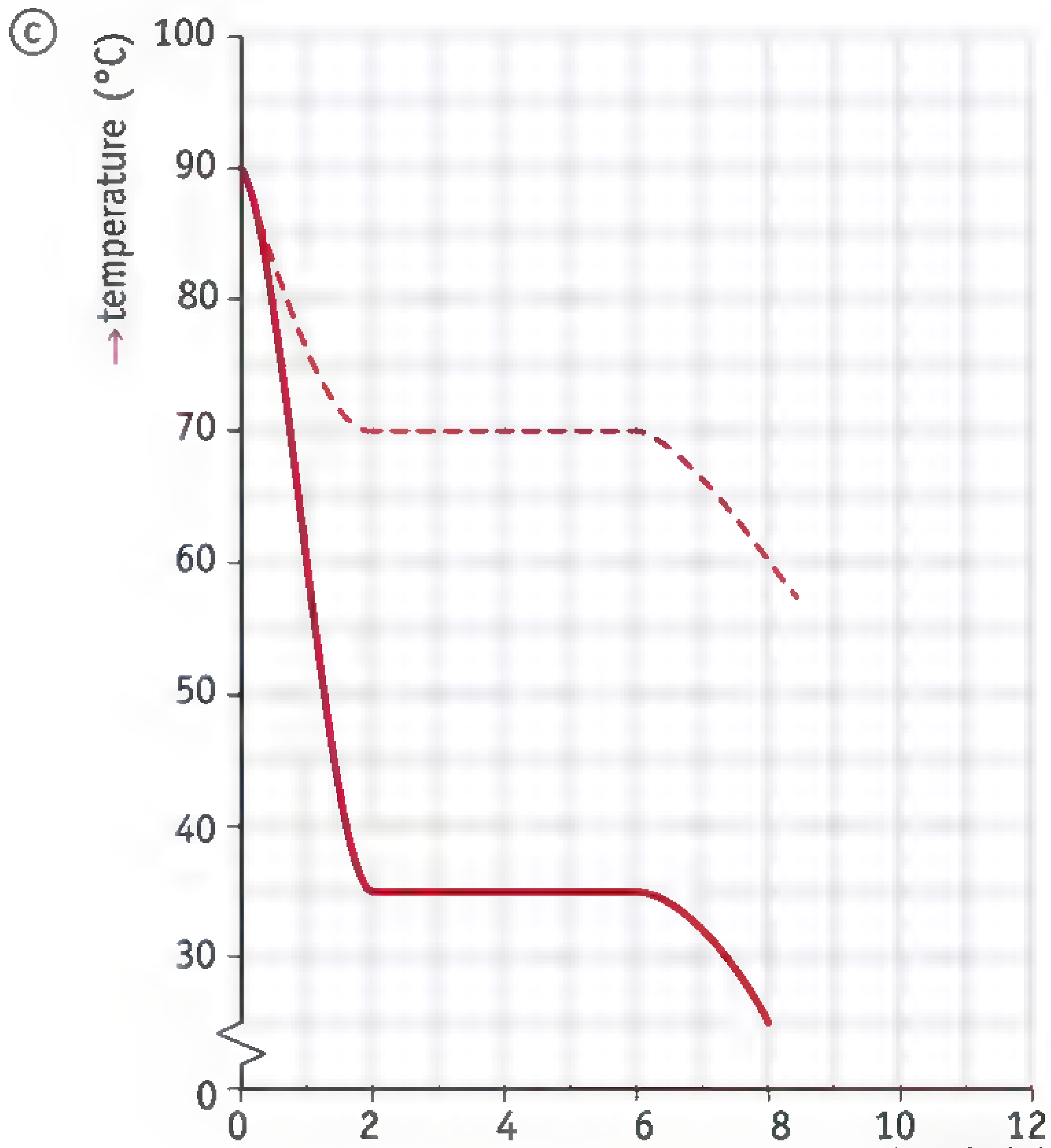
figure 8 Which graph is correct?



a



b



c

★ 10

In a demonstration, liquid nitrogen is poured from a Dewar flask (a kind of thermos) into a glass beaker (figure 9).

a How is it possible for the nitrogen to start 'spontaneously' boiling?

b What is the temperature of the boiling nitrogen in the glass beaker?

c What is the white mist around the glass beaker made of?

d Ice appears on the glass beaker. Explain why this happens.

figure 9 A demonstration with liquid nitrogen.

Test what you know with *Test yourself.*

EXTRA THE BOILING CURVE OF A MIXTURE

11 On a bottle of white spirits, it says 100/140. These numbers represent the boiling curve of the white spirits, in degrees Celsius (figure 10).

a The label states the ‘boiling point’. Why is that actually incorrect?

b If you heat white spirits, the liquid will begin to boil after a couple of minutes.
What will a thermometer read if you hold it in the white spirits then?

c What will the thermometer read when almost all the white spirits have evaporated?

d Determining the boiling curve of white spirits is not difficult. However, this experiment is not one that is ever done at school.
Think up two reasons why this experiment is not allowed to be done at school.

figure 10 The label on a bottle of white spirits.

12 You need graph paper for this exercise.
Rohan is melting a quantity of beeswax in a test tube. As it progresses, he measures the temperature. You can see his measurements in table 3.

a Draw the melting diagram for this experiment on the worksheet.

b How many minutes does it take before the beeswax starts to melt? .... minutes

c What is the temperature then? .... °C

d After how many minutes has all the beeswax melted? after .... minutes

e What is the temperature then? .... °C

f Is beeswax a pure substance or a mixture? How can you see that?

table 3 Rohan’s measurements.

time (min)	temperature (°C)
0	20
1	31
2	40
3	43
4	46
5	49
6	51
7	54
8	57
9	60
10	71
11	83

Experiments

EXPERIMENT 1 CALIBRATING A LIQUID THERMOMETER

30 minutes

Introduction

A liquid thermometer has a reservoir and a riser capillary that has a scale marked along it in degrees Celsius (°C), which you can use to read off the temperature.

Goal

In this experiment, you are going to add a graduated scale to a thermometer.

Requirements

- ☐ masking tape
- ☐ glass beaker
- ☐ ice blocks
- ☐ an ungraduated thermometer
- ☐ an ordinary thermometer
- ☐ Bunsen burner
- ☐ tripod
- ☐ wire mesh
- ☐ matches/lighter

Doing the experiment and writing it up

Determining the zero point

- Stick a narrow strip of masking tape close to the riser capillary.
- Place the ice blocks in the glass beaker. Put the thermometer in with them. The reservoir must be surrounded on all sides by the ice blocks (figure 1).
- Wait for two minutes. Then put a pencil mark on the masking tape showing where the alcohol level is.
- Remove the thermometer from the ice and write the number 0 next to the mark.

figure 1 The thermometer in ice water.

Determining the hundred point

- Fill the beaker one third full with water. Use the Bunsen burner to heat the water until it is boiling.
- Put the thermometer in the glass beaker. Leave the thermometer in the boiling water for one minute. Then make a pencil mark on the masking tape at the point the liquid has reached.
- Turn the burner off. Take the thermometer out of the water. Write the number 100 next to the mark that you have just made.

Calibration and measurement

- Add marks to subdivide the space between the 0 and 100 into ten equal parts. Put the numbers 10 to 90 next to the marks.
- Measure the temperature in the classroom using the thermometer that you have just made a graduated scale for. Try to determine the temperature to an accuracy of one degree. Then measure the temperature in the classroom again, but this time with an ordinary thermometer.

1 What temperatures do each of the thermometers give?

....

- Use both thermometers in the same way to measure the temperature of tap water immediately after it comes out of the tap.

2 What temperatures do each of the thermometers give?

....

- Use both thermometers as well to measure the temperature of your body. Hold the reservoir of each thermometer under your armpit for 30 seconds before reading the temperature.

3 What temperatures do each of the thermometers give?

....

4 Can you use the thermometer that you have just added a graduated scale to for measuring temperatures reasonably accurately?

....

....

EXPERIMENT 2 EVAPORATION AND WIND CHILL

15 minutes

Introduction
When you get out of the swimming pool in the summer, you will notice that the wind affects how you perceive the temperature. If there is no wind, the apparent temperature is warmer than if there is a stiff breeze. This is because the wind makes the water on your skin evaporate more quickly.

Goal
In this experiment, you study 'wind chill': the effect of evaporation on the apparent temperature (the temperature as you actually feel it).

Requirements
- ☐ dropper bottle of water
- ☐ dropper bottle of ethanol
- ☐ dropper bottle of nail varnish remover

Doing the experiment and writing it up
- Put a drop of water on the upper side of your forearm.
- Blow on it until the drop has evaporated.
- Put the same size drop of ethanol on your arm.
- Blow on it until the drop has evaporated.
- Put the same size drop of nail varnish remover on your arm.
- Blow on it until the drop has evaporated.

1 What did you feel while they were evaporating?

....

....

2 Which liquid evaporates fastest?

....

3 Which liquid feels coldest?

....

4 What link is there between the evaporation of liquids and the perceived temperature?

....

....

....

EXPERIMENT 3 BOILING WATER

30 minutes

Introduction
When you heat a substance, its temperature increases. You see that for example when you boil water for a cup of tea.

Goal
In this experiment, you are going to investigate for yourself how the temperature changes.
The question you are studying is:
How does the temperature of water change when you bring the water to the boil?

Requirements
- ☐ glass beaker
- ☐ thermometer
- ☐ a watch
- ☐ Bunsen burner
- ☐ tripod
- ☐ wire mesh
- ☐ matches/lighter
- ☐ graph paper

Doing the experiment and writing it up
Sharing the work
You do this experiment in pairs:
- Pupil 1 reads the temperature from the thermometer.
- Pupil 2 keeps track of the time and writes down the measurement results.

Preparation
- Put exactly 100 mL water in the glass beaker. Then set the experiment up as shown in figure 2.

1 Write down the temperatures that you read off in table 1.

table 1 The measurements for Experiment 3.

time (min)	temperature (ºC)	time (min)	temperature (ºC)
0.0		4.0	
0.5		4.5	
1.0		5.0	
1.5		5.5	
2.0		6.0	
2.5		6.5	
3.0		7.0	
3.5		7.5	

- Measure the initial temperature of the water.
- Light the Bunsen burner as you have been taught. Turn the gas control knob half open.
- Turn the air control knob far enough open that you get a flame that burns steadily (without making a lot of noise).
- Place the burner under the glass beaker on the tripod (figure 2).
- Read the thermometer off every thirty seconds. Keep the reservoir of the thermometer about 1 cm above the bottom of the beaker while making the measurement.
- The water will eventually start boiling. Take four more temperature readings after that.
- Turn the burner off after the final measurement.

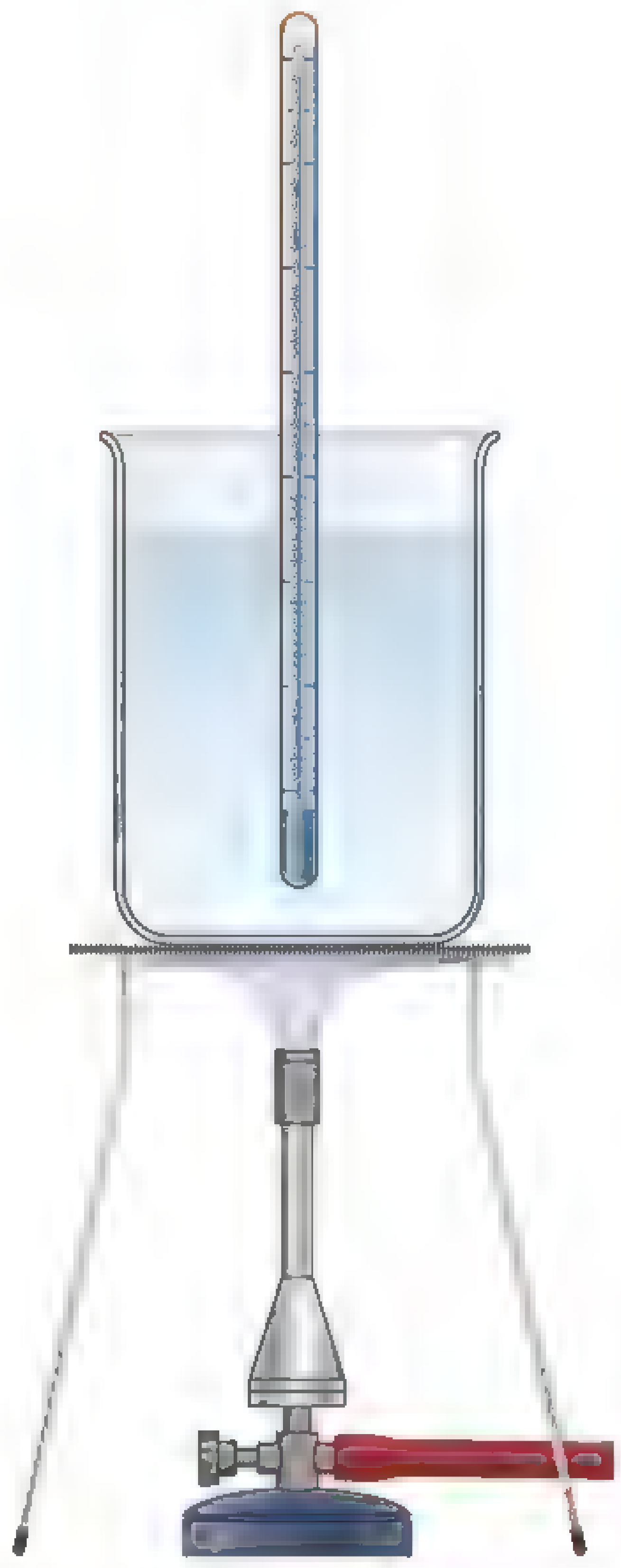


figure 2 The setup for Experiment 3.

2 How could you see that the water was boiling?

....

- See how much water is left in the glass beaker.

3 Has any water disappeared from the beaker? If so, where did that water go?

....

....

Writing up

4 Draw the graph for this experiment. First, draw in your measurements as a series of points. Then draw a single smooth line that passes through the measurement points as closely as possible. In other words, you should not simply join the dots together one by one with a ruler.

See the skills section on *Working with tables and graphs*.

EXPERIMENT 4 DETERMINING THE BOILING POINT OF ALCOHOL

20 minutes

Introduction
Every pure substance has a boiling point. This is the temperature at which the substance boils. The boiling point is a property of the substance, so it is different for different substances. You can therefore identify a substance by its boiling point.

Goal
In this experiment, you are going to determine the boiling point of pure ethanol (= ordinary alcohol). Because ethanol is highly flammable, you will be doing the experiment in a special way.

Requirements
- ☐ glass beaker
- ☐ test tube with ethanol
- ☐ thermometer
- ☐ a watch
- ☐ gas burner (Bunsen burner)
- ☐ tripod
- ☐ wire mesh
- ☐ matches/lighter

Doing the experiment and writing it up
Preparation
- Put 200 mL water in the glass beaker.
- Heat the water with the burner. Use a blue flame that burns steadily (without making a lot of noise).
- Wait until the water boils. Then turn the burner off.
- Wait until your teacher has also turned off the main gas tap.

Measuring
- Place the thermometer in the ethanol in the test tube.
- Put the test tube with the ethanol into the hot water.
- Read off the temperature until there is no longer any change.

1 How does the temperature of the ethanol change during the experiment?

....

....

....

2 What do you see happening to the ethanol when the temperature is no longer increasing?

....

....

....

3 What is the boiling point of ethanol, according to this experiment?

....

- Smell the air close to the experimental setup and note the odour you observe.

4 Try to describe the smell.

....

....

....

5 So what has happened to the ethanol?

....

....

....

EXPERIMENT 5 MAKING A CHILLING MIXTURE

15 minutes

Introduction

When it is hot in the summer, lots of people enjoy eating a nice, cold ice cream. If you want to make ice cream, you have to make sure that the ingredients get cold enough for them to freeze. There are special ice-making machines for this, or you can also use a chilling mixture.

Goal

This experiment will show you how you can use a mixture of salt and ice to generate temperatures of well below 0 °C.

Requirements

- ☐ glass beaker with 150 mL finely crushed ice
- ☐ thermometer
- ☐ table salt
- ☐ spoon
- ☐ test tube
- ☐ drink mix syrup/cordial
- ☐ stirring rod

Doing the experiment and writing it up

- Measure the temperature of the melting ice and write it down.
- Add three good scoops of salt to the ice and stir the mixture for a few moments.

1 What do you see happening as you add the salt and stir it?

....

....

....

- Put the thermometer back in the ice and salt mixture straight away.

2 Write down the temperature every 15 seconds. Carry on doing this until the temperature is no longer changing.

....

....

....

....

....

- Put a small amount of the drink syrup or cordial (about the thickness of your index finger) into the test tube and put it in the melting ice.

3 What happens to the syrup? Why?

....

....

....

EXPERIMENT 6 CARRYING OUT RESEARCH: COOLING BY EVAPORATION

30 minutes

Introduction

Suppose that a laboratory equipment manufacturer wants to develop a cooling device that will allow very low temperatures to be reached. The designer is asked to make use of the cooling effect of rapidly evaporating liquids. The question is then which liquid should be used to achieve the lowest temperatures. The research department is brought in for this problem. In this exercise, you are the scientist who has to carry out the study.

Goal

In this experiment, you will be examining how far you can lower the temperature using three evaporating liquids: water, ethanol and nail varnish remover. You must compare the three liquids as fairly as possible.

Requirements

For this experiment, you have to think up for yourself what equipment you will need.

Doing the experiment and writing it up

- Think about how you can give the most reliable answer to the question. What are you going to measure, what items will you need for the experiment and how can you measure each liquid under exactly the same conditions?

1 Make a work plan for this study.

- The work plans will be discussed with the rest of the class in the next lesson. If necessary, you can make improvements to your own work plan after that.
- Then carry out the experiment.

2 Write down all the measurements, calculations and results.

- Your teacher will tell you whether or not you have to write up a report on this experiment.

EXPERIMENT 7 PRODUCING A DESIGN: THE RAIN GAUGE

90 minutes

Introduction

Suppose that your school is going to do a weather project in which the pupils will be gathering their own data about the weather. One of the weather parameters is the amount of precipitation (rain, snow, hail, etc.) that has fallen over the previous 24 hours. The idea is that the pupils must make a reliable rain gauge for this themselves. You are given the task of designing such a meter.

Goal

In this experiment, you will be designing, making and calibrating a rain gauge. Your prototype must meet the following design requirements:

Design requirements

- The rain gauge must be made of materials that are cheap or cost nothing. You can find ideas for this on the Internet.
- The graduated scale must show the number of millimetres of rain that have fallen since the last measurement. (That is how deep the water would be if the rain did not run off, evaporate or sink into the soil.)
- The rain gauge must 'multiply up' the rise in the water level by a factor of at least five: if 1 mm rain falls, the level of the water in the rain gauge must rise by at least 5 mm.
- The rain gauge must easily be 'zeroed' again after each measurement.
- The rain gauge must be stable and sturdily constructed. It must be possible to make measurements with it without difficulty for at least two weeks, even in bad weather.
- The graduated scale on the gauge must be calibrated: you must have checked whether the markings and numbers have been applied correctly.

Requirements

For this exercise, you have to think up for yourself what equipment you will need. Discuss it if necessary with your teacher.

Doing the experiment and writing it up

- Think how you can carry out the exercise. What components will your gauge contain, what items do you need, how can you test whether the graduated scale is correct?

1 Make a work plan for this exercise.

- The work plans will be discussed with the rest of the class in the next lesson. If necessary, you can make improvements to your own work plan after that.
- Construct the rain gauge and calibrate it carefully.

2 Make a test report that includes:
  a a clear diagram showing how the rain gauge is constructed.
  b the tests you carried out and the results you got from them.
  c any changes that you made to the design.

The explosive power of steam

First you hear the water bubbling and then the hiss of escaping steam. Then the ground under your feet starts to shake. Suddenly, a column of steam and boiling water 50 metres high shoots up out of the ground. While the clouds of mist float away on the wind, the eruption continues unabated for nine or ten minutes. Then the geyser stops again, almost as suddenly as it started. If you are lucky, there will be another show in eight hours' time or so.

Steam from a geyser

The eruption of a large geyser is an impressive piece of theatre. The power that forces the jet of water upwards is massive. That power comes from superheated steam that has been formed deep under the volcanic soil (several kilometres down). A geyser occurs when the subterranean structure means that the steam cannot easily escape from the ground. The pressure keeps building up until it can no longer be contained. The steam then escapes explosively, with a force that blows tons of hot water into the air.

A steam turbine that is two thousand years old

The fact that steam can exert a force was already known two thousand years ago. That was when Hero of Alexandria, a Greek scientist and inventor, built the world's first steam turbine. It was a primitive machine – to us it looks more like a toy than a serious piece of apparatus – but the thinking behind it was correct. A modern steam turbine works on the same principles.

Figure 1 shows you how Hero's invention works. Water was heated in a steam kettle. The steam that this created was passed through two hollow pipes and into a rotatable ball. The steam could escape from there through two bent nozzles. The force that this exerted was enough to get the ball spinning at quite a speed.

The *aeolipile* (the name Hero gave to his invention) could spin for hours using just a few litres of water. This is because a small amount of water can generate a vast quantity of steam. If steam is allowed to expand without restriction, 1 litre of water can generate no less than 1600 litres of steam. Hero's *aeolipile* does not manage that, because the steam can escape from the device through two narrow openings. Even so, 1 litre of water is all you need here to create hundreds of litres of steam.

Trapping steam

If you boil water in a saucepan, the steam can escape in lots of directions. The steam does not have to push hard to create more space for itself. This creates a vast amount of steam, but no large forces. You see the same in volcanic areas where the steam can escape easily from the soil. This creates hot springs that bubble away and emit clouds of mist all the time, but no geysers that suddenly burst forcefully into life.

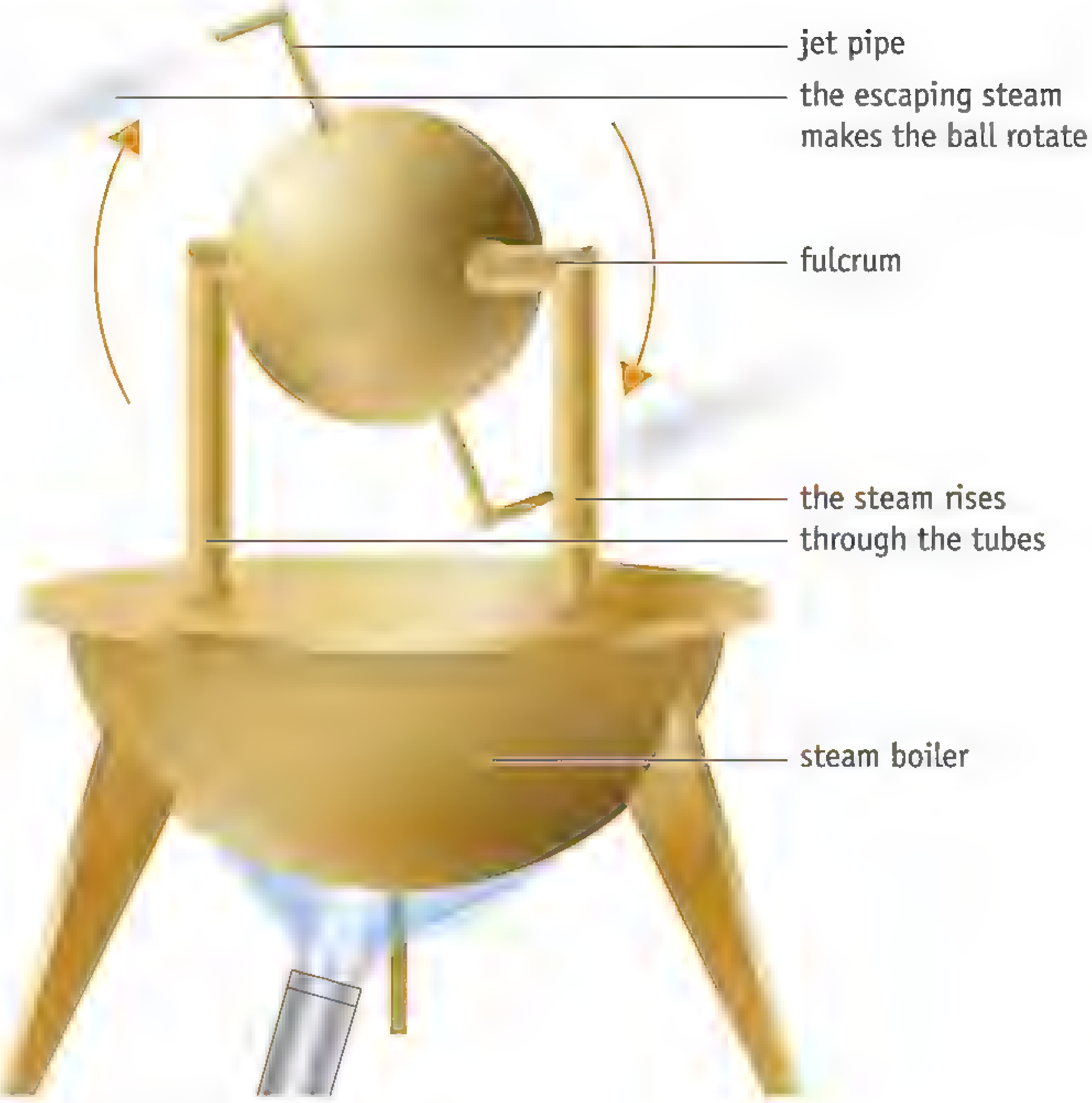


figure 1 Hero's *aeolipile*.

Steam explosions

The power of steam can also be dangerous. A boiler or pipe that contains high-pressure steam can suddenly break, because of a construction error or through age or poor maintenance. The steam then flows out with an irresistible force, blowing aside everything in its path. People can be injured not only by the hot steam but also by the debris flying around.

On 19 July 2018, an underground steam pipe beneath a busy crossroads in New York exploded (figure 3). The steam blew water and mud more than forty metres into the air. Dozens of buildings near the famous *Flatiron* building had to be evacuated. The cause: a weak spot in an 89-year-old steam pipe.

To make steam exert a force, you have to enclose it in a small space, such as the boiler of Hero's *aeolipile*. When the water in the kettle boils, increasing amounts of steam are generated that cannot immediately escape. The pressure in the boiler and the ball therefore builds up a lot – and that is exactly what is needed to make the steam escape forcefully through the small jet nozzles.

Steam under high pressure is extremely suitable for making objects move. There is nowhere that demonstrates this better than a modern electricity generating station (figure 2). Steam boilers forty metres tall produce steam for a series of turbines in the machine hall. The turbines are made to rotate by the extremely hot steam, which blows against the turbine blades – in the same way as the wind makes windmills go round, but this is many times more powerful. In turn, the turbines power the generators that provide electrical energy for hundreds of thousands of people.

figure 2 A modern power station (electricity generating station).

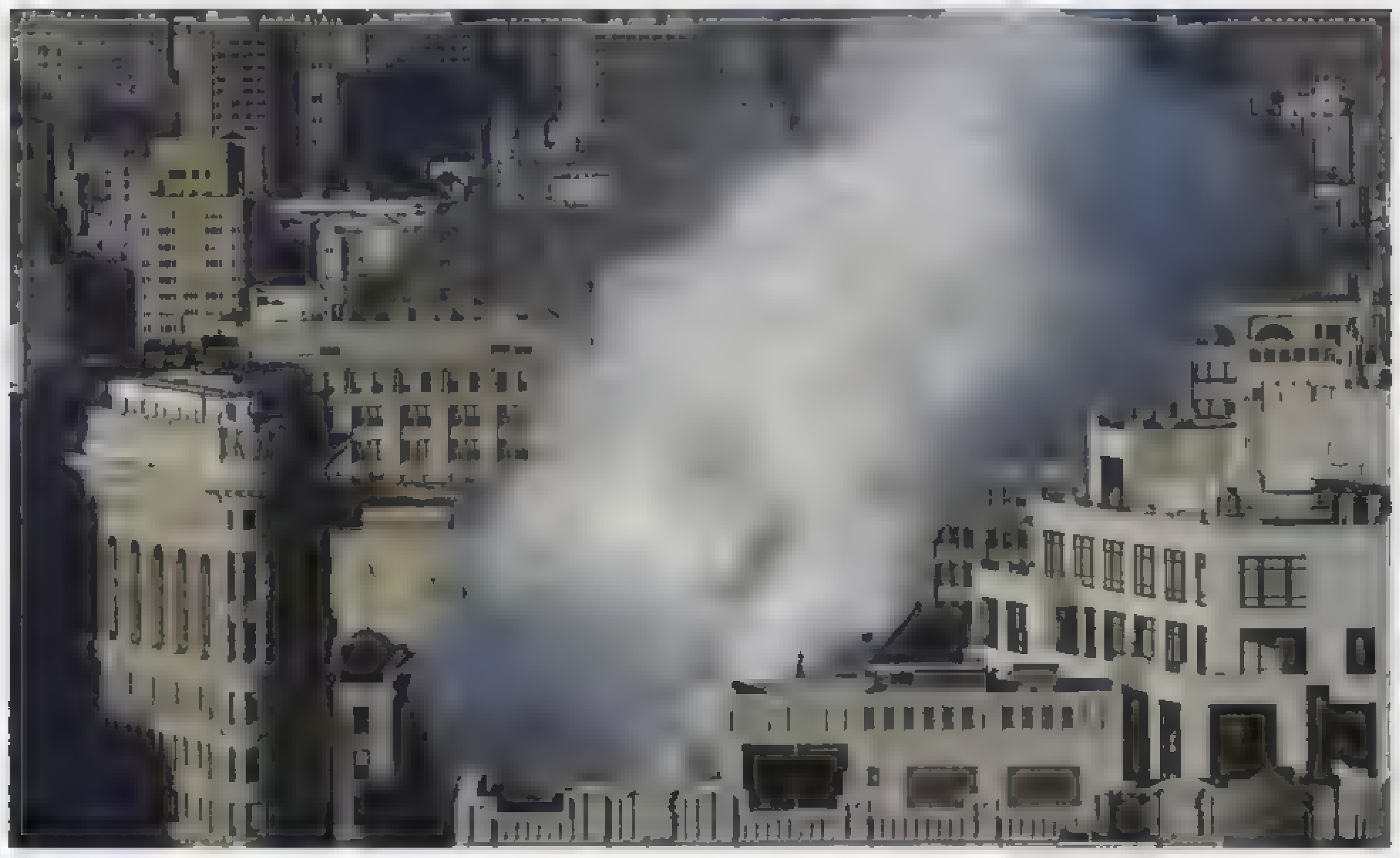
The explosive power of steam is also the reason why you must NEVER attempt to put out a chip pan fire with water. The combination of water plus hot burning fat is extremely dangerous. When the water comes into contact with the molten fat, it will turn into steam incredibly quickly. The steam explosion that this causes will then expel burning fat in all directions, creating a large fireball that will set everything around it alight.

Caution... steam!
Steam boilers are designed carefully so that they can withstand the enormous forces produced by the steam. The designers also build in a safety margin, so even if the pressure does go above the maximum value allowed, you will not immediately have wreckage flying about your ears. There are all kinds of safety features as well. If the pressure in the boiler rises too far, safety valves will open immediately. This allows the steam to escape so that the pressure in the boiler falls. You will then see a big cloud of mist outside the boiler, as the hot steam condenses in the cold outside air.

Less attention was paid to safety at the start of the steam age, which is about two hundred years ago now. But so many accidents occurred that this situation soon changed.

figure 3 Damage in Manhattan.

New York hit by a steam explosion



An explosion in an underground pipe caused chaos in New York's morning rush-hour. The explosion created a geyser that sprayed clouds of water vapour high above Manhattan.
The incident happened on the corner of the well-known shopping street Fifth Avenue and 21st Street. Chunks of asphalt flew onto the street and a crater appeared in the middle of Fifth Avenue. Water and gas pipes and electricity cables were also damaged by the explosion. Buildings in the vicinity were evacuated and traffic was halted in the surrounding streets.
The steam pipeline network under the streets of Manhattan was laid to provide heating for skyscrapers and businesses. Some businesses also use the steam for cleaning purposes.
From: nos.nl.

The Steam Act came into force in the Netherlands in 1824. This contained numerous regulations that were intended to improve safety. People back then may have found all the regulations to be annoying at times, but safety did improve enormously as a result.

Old-fashioned steam engines are now virtually a thing of the past, but steam turbines are still very much going strong. They generate 80% of all the electrical energy that is consumed worldwide. Even a nuclear power plant cannot manage without steam turbines for converting heat into motion. Electricity has therefore not made steam redundant but has instead only moved it... into the power station. So if you think about it carefully, you will see that even your mobile and laptop are powered indirectly by steam.

DID YOU KNOW...

New York has the largest commercial steam network in the world, with about 160 km of pipes. More than a hundred thousand businesses and homes are connected to the system. The key applications are home heating, hot water and air conditioning. Some of the steam pipes are now over a hundred years old.

EXERCISES

1 Explain why:

a geysers do not occur in areas where the ground is easily permeable for water and steam.

b the pressure in the kettle and ball of Hero's *aeolipile* increases when the water in the kettle starts to boil.

c you are taking a huge risk if you try to put out a chip pan fire with water.

2 Big clouds of white 'mist' are always produced when there is a steam explosion.

a What substance are these mist clouds made of? What phase is the substance in?

b The media talk about 'clouds of steam' and 'clouds of water vapour'.
Why are these terms rather inaccurate from a scientific point of view?

c A newspaper report states that "the clouds of steam soon dissolved again".
Translate this sentence from everyday or media language into scientific language.

3 Take a look at the two types of safety valves shown in figure 4.

a Explain how the upper safety valve works.

b Explain how the lower safety valve works.

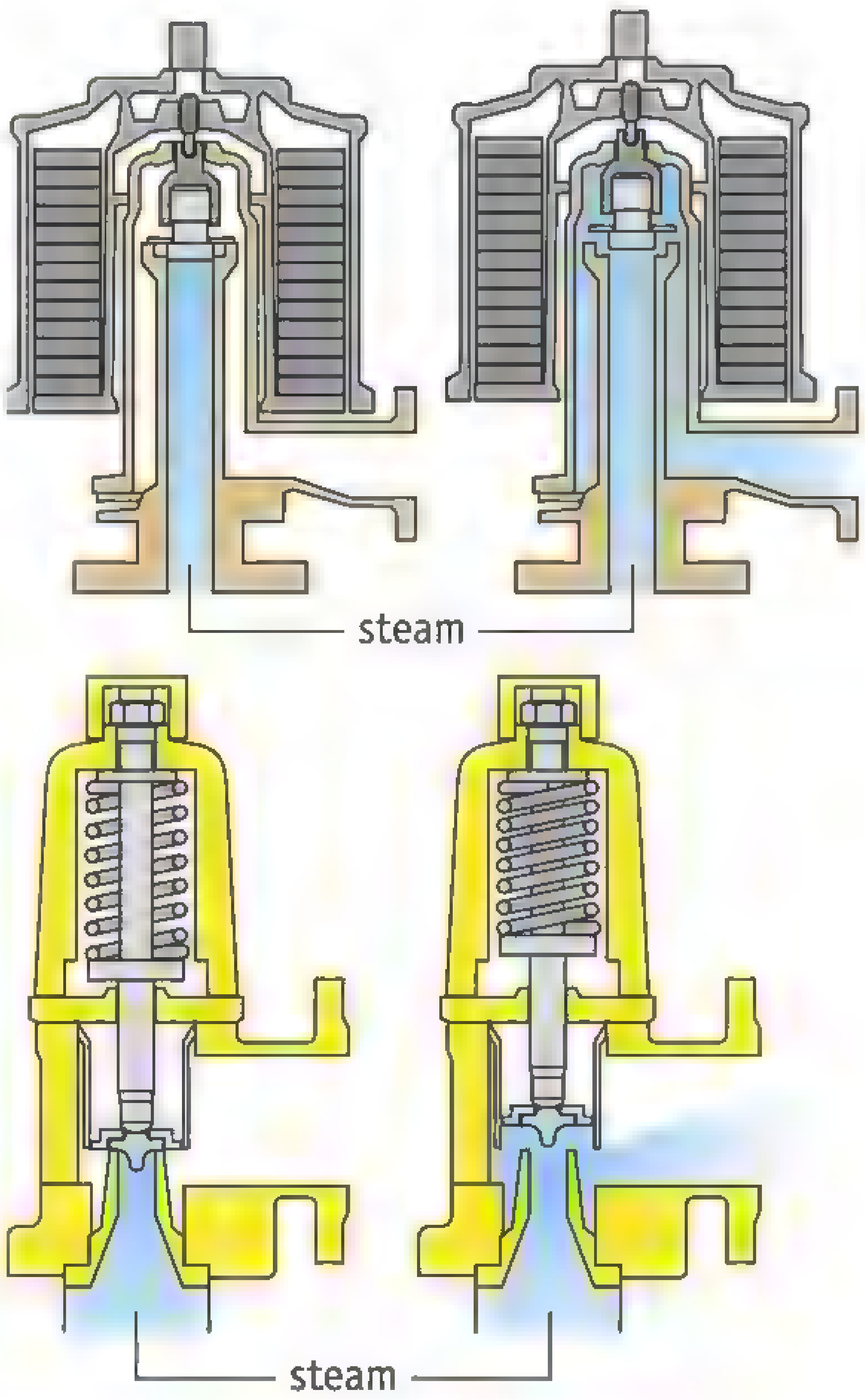


figure 4 Two safety valves.

Course material overview

3.1 ICE, WATER, WATER VAPOUR

REMEMBER

- Substances can occur in three phases: solid, liquid and gas.
- The particle model gives you a picture of those three phases. The molecules of a substance are the same in every phase but they move differently:
  - In a solid, the molecules are vibrating back and forth around their own fixed positions. So a solid substance has a fixed volume and a fixed shape.
  - The molecules in a liquid move past each other in all possible directions but keep as close together as possible. So a liquid has a fixed volume but does not have a fixed shape.
  - The molecules in a gas move freely and independently of one another, spreading out to fill the space containing them. This means that the average distance between the molecules is very large. A gas has neither a fixed volume nor a fixed shape.
- In many solid substances, the molecules are stacked in regular patterns. This creates a crystal lattice

CONCEPTS

crystal lattice
A regularly stacked structure of the molecules of a substance. Every molecule has its own fixed position in that lattice.

crystal structure
A characteristic, regular structure of many solid substances.

gas
Phase in which all the molecules of a substance can move independently of one another. The molecules are all relatively far apart.

liquid
Phase in which all the molecules of a substance can move past one another. The molecules remain as close to each other as possible.

particle model
A model in physics and chemistry that assumes substances are made up of molecules.

phases
Three states that a substance can be in: solid, liquid or gas.

solid
Phase in which all the molecules of a substance vibrate around their fixed positions.

3.2 TEMPERATURE

REMEMBER

- A thermometer lets you measure temperatures. The unit of temperature that is widely used in everyday life is the degree Celsius (°C).
- If you measure the temperature of the air with a thermometer, you get a numeric value that is independent of your sense of touch.
- A liquid thermometer consists of a reservoir and a riser capillary with a graduated scale alongside. In a liquid thermometer, the liquid in the capillary tube rises when the temperature goes up. This is because the liquid expands.
- The Celsius temperature scale is based on two fixed points: the temperature of melting ice is 0 °C and the temperature of boiling water is 100 °C. The range in between is split up into a hundred equal parts.
- The difference between the lowest and highest ranges that you can measure with the thermometer is called the measurement range.
- On a digital thermometer, you read the temperature off from a screen. This type of thermometer works electronically.

CONCEPTS

capillary tube
A thin transparent tube in which a liquid level can rise and fall.

digital thermometer
A thermometer with which you read the temperature off from a screen.

liquid thermometer
A thermometer consisting of a reservoir filled with liquid and a riser capillary tube.

measurement range
The difference between the lowest and highest temperatures that you can measure with a measuring instrument.

reservoir
The space at the bottom of a liquid thermometer that is filled with liquid.

thermometer
An instrument for measuring temperature.

3.3 PHASE CHANGES

REMEMBER

- In a phase transition, a substance changes from one phase into another.
- There are six phase transitions
  - melting is when a solid changes into a liquid;
  - freezing or solidification is when a liquid changes into a solid;
  - evaporation is when a liquid changes into a gas;
  - condensation is when a gas changes into a liquid;
  - deposition is when a gas changes into a solid;
  - sublimation is when a solid changes into a gas.
- Phase transitions play an important role in all sorts of weather phenomena.
- What happens in a phase transition can be described using the particle model:
  - When the temperature of a solid rises, the molecules will vibrate more so that they move further apart at times. The distance between the molecules can then become so great that the attractive forces are too small to hold them in place. The substance then melts and becomes liquid.
  - The molecules in a liquid are moving in all possible directions. Molecules that are close to the surface of the liquid may then have enough speed to escape from the liquid. The liquid then evaporates and becomes a gas.

CONCEPTS

condensation
Phase transition in which a substance changes from gaseous to liquid.

deposition
Phase transition in which a substance changes from gaseous to solid.

evaporation
Phase transition in which a substance changes from liquid to gaseous.

freezing
Another name for solidifying, specifically used for liquids that become solid at temperatures below 0 °C.

melting
Phase transition in which a substance changes from solid to liquid.

phase transition
When a substance changes from one state into another.

solidification
Phase transition in which a substance changes from liquid to solid.

sublimation
Phase transition in which a substance changes from gaseous to solid.

3.4 BOILING POINT AND MELTING POINT

REMEMBER

- When water boils, the bubbles of vapour that appear throughout the liquid can reach the surface of the water.
- When a liquid is heated, the temperature rises until the boiling point is reached. The temperature remains constant during boiling.
- When a solid is heated, the temperature rises until the melting point is reached. At the melting point, the solid substance becomes liquid. The temperature remains constant during melting. The temperature at which a liquid becomes solid as it cools is called the solidification point. For water, this is called the freezing point rather than the solidification point.
- You can lower the freezing point of water by adding a suitable substance to the water (salt or antifreeze).
- If you heat a solid substance and measure its temperature regularly before, during and after melting, you can then draw a melting diagram.
- If you cool a liquid and measure its temperature regularly before, during and after solidification, you can then draw a solidification diagram.

CONCEPTS

boiling
The process in which a liquid evaporates not only at the surface but throughout the liquid.

boiling point
The temperature at which a liquid starts to boil. The boiling point is a distinctive property of a substance.

freezing point
The temperature at which a substance solidifies (the word mostly used when it is 0 °C or lower, such as for water). The freezing point (or solidification point) is a distinctive property of a substance.

melting diagram
A graph showing how the temperature progresses during the melting process for a specific substance.

melting point
The temperature at which a solid substance melts. The melting point is a distinctive property of a substance.

solidification diagram
A graph showing how the temperature progresses during the solidification process for a specific substance.

Go to the *Flash cards* and the *Diagnostic test*.

4 Electricity

PORTABLE DEVICES

An electrical device that runs on batteries can be taken with you and used wherever you want. You don't have to worry about a cable that has to be plugged into a socket. Of course, you do have to recharge or change the batteries in time.

1 Making an electrical circuit

LEARNING OBJECTIVES

4.1.1 You can explain how to make a closed circuit.
4.1.2 You can list the various components of an electrical circuit.
4.1.3 You can explain the difference between conductors and insulators.
4.1.4 You can list various conductors and insulators.
4.1.5 You can explain how you measure a current.
EXTRA 4.1.6 You can explain what a LED is and how it works.

TAXONOMY	LEARNING OBJECTIVES AND EXERCISES					
	4.1.1	4.1.2	4.1.3	4.1.4	4.1.5	4.1.6
Remembering	1a	1d	1c, 2a	1b, 3	2bc	
Understanding					5, 6ab, 7abcdefghij	12a, 13
Using	4, 10, 11		8, 9			
Analysing						12b

You will find all sorts of devices in your home that run on electricity. Appliances that use a lot of energy, such as a vacuum cleaner or a washing machine, have to be plugged into the mains. But there are also lots of electrical devices that run on batteries.

A CLOSED ELECTRICAL CIRCUIT

To light a bulb, you need to pass an electric current through it. This is only possible if you make a closed **circuit**. This could for instance go from one terminal of a battery, through the bulb and back to the other side of the battery (figure 1).

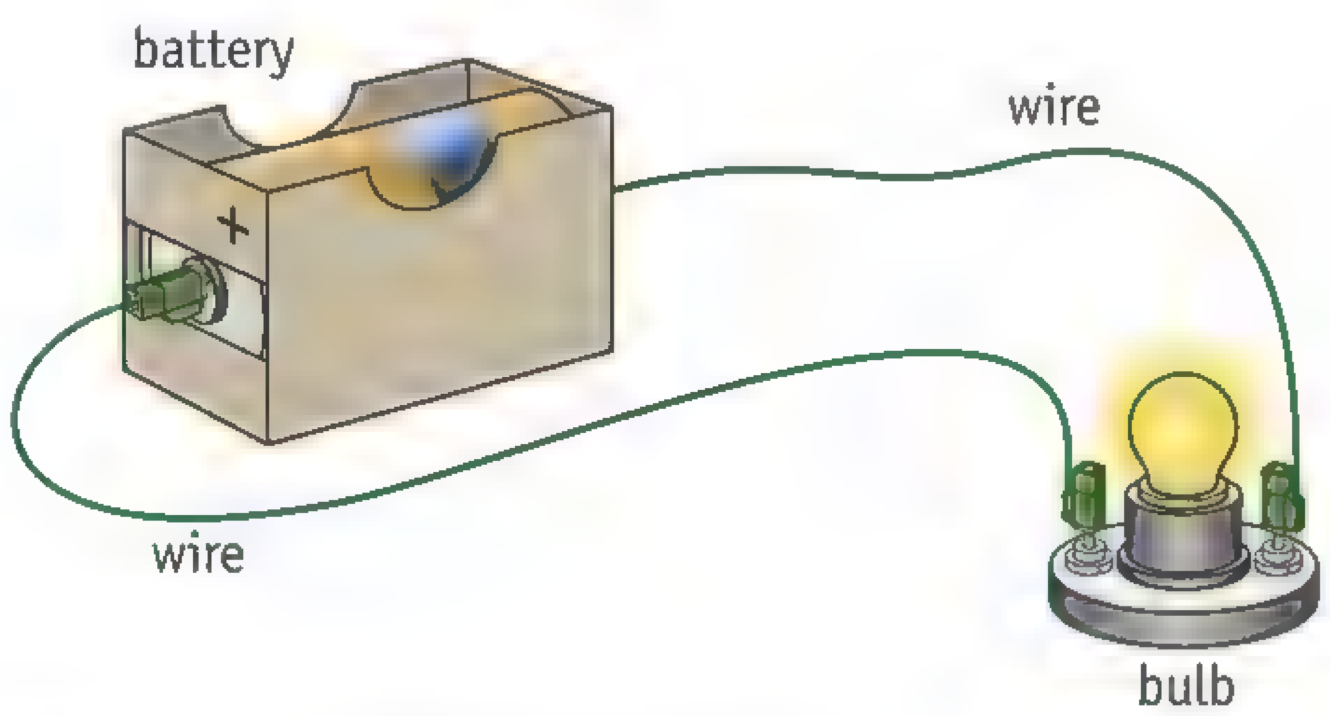


figure 1 A closed electrical circuit.

The words 'current' and 'circuit' make clear that *something* is moving through the wires and the bulb. Physicists have called that 'something' a **charge**. An electrical current consists of moving charge. When you break a circuit, that movement stops. The charge is still there, but it can no longer move through the circuit.

You can compare the movement of charge to an airflow. In both cases, the movement itself cannot be seen. What you *can* see is the effect of the motion. When you close the circuit, you see the bulb light up. When it is windy outside, you can see wind turbines going round.

INSULATING AND CONDUCTING SUBSTANCES

There are various ways of connecting the components of a circuit together. For experiments with electricity, you use wires. The electrical current flows through the actual copper wire that makes up the core of the cable. The outside of the cable (also generally called a “wire”) is plastic. Electrical currents do not flow through the plastic (figure 2).

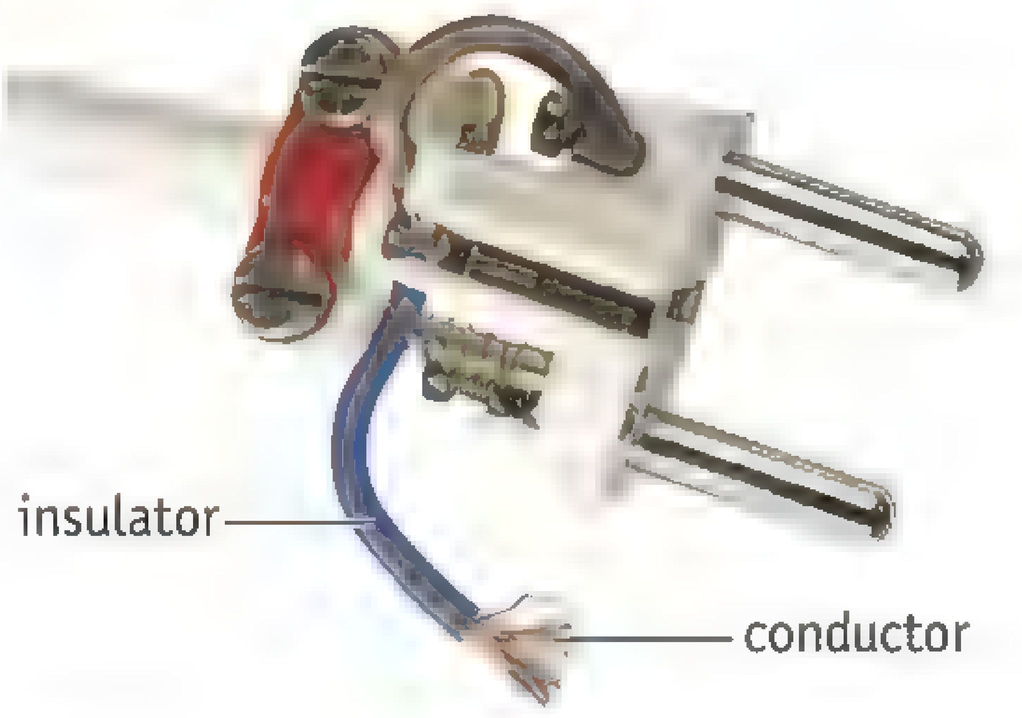


figure 2 A plug and an electrical wire consist of conductors and insulators.

Substances that electric currents can flow through easily are called **conductors.** All metals are conductors, but some metals conduct better than others. Copper and aluminium, for example, are better conductors than iron and lead. Carbon is not a metal, but in some cases it too can conduct.

Substances that do not allow electrical currents to pass through them (or only very poorly) are called **insulators.** Examples are rubber, glass and most plastics. If a solid substance is not a metal, it will almost always be an insulator. Air is also a good insulator.

In a closed electrical circuit, the current flows through the conducting parts of the wires, bulbs or other devices. You can use a **switch** to turn the current on and off (figure 3). When you switch the current on, two conducting parts of the switch come into contact. This closes the circuit.

When you use the switch to turn the current off, there is no longer a conducting connection. The circuit is then open and the electricity can no longer flow through the bulb. When the circuit is open, the bulb will therefore not be lit.

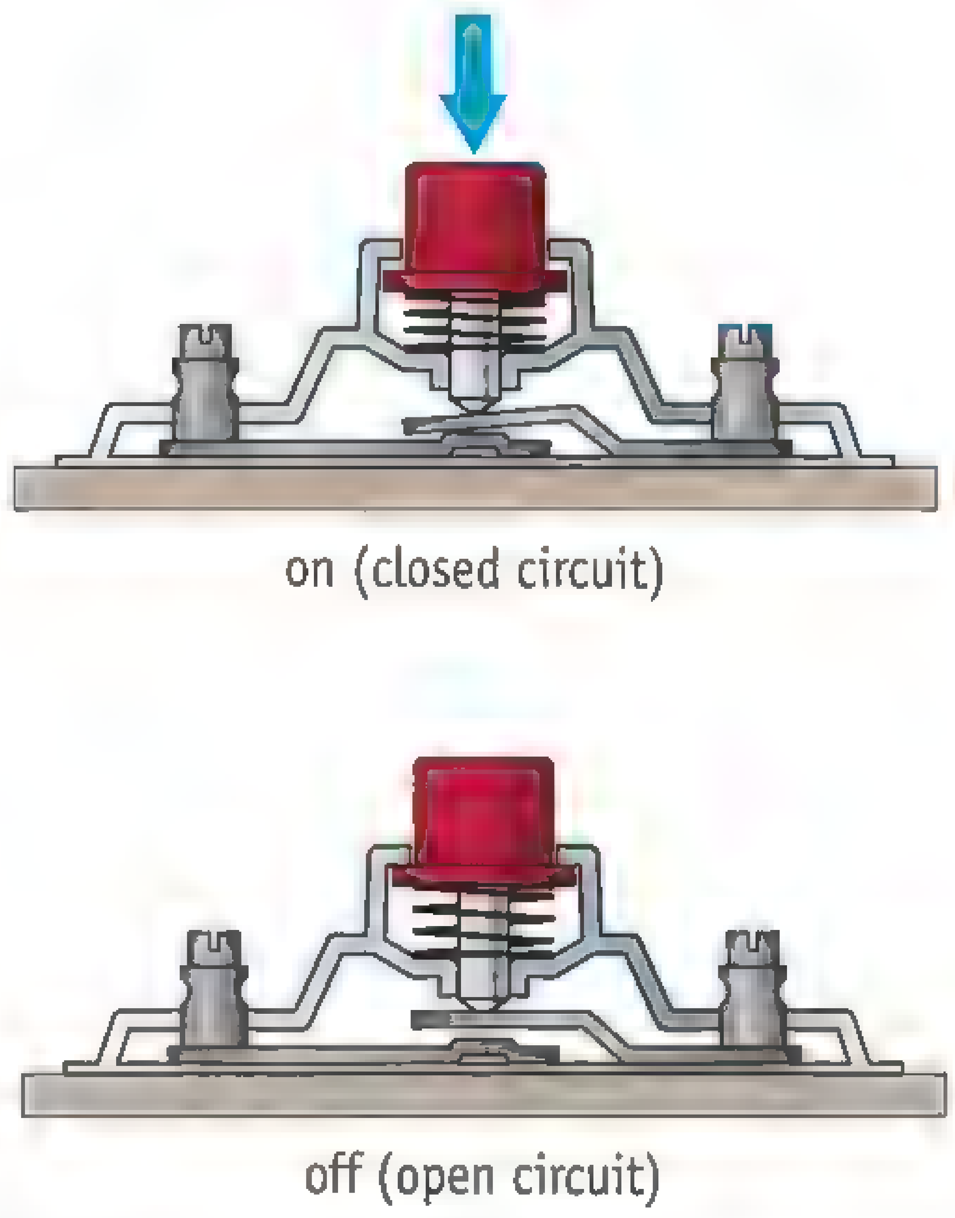


figure 3 Two types of switch.

MEASURING CURRENTS

You can use an **ammeter** to measure how ‘strong’ the electric current is that is flowing through a circuit. At some given point in the circuit, you measure how much charge passes in one second. This is known as the **current.** The more charge passes that point per second, the greater the current.

You can compare the current to the amount of air coming out of an inflated balloon every second. If you open the balloon’s neck (which is acting as a valve) just a little bit, the air flows out. The greater the ‘current’, the sooner the balloon is empty.

The unit of electrical current is the ampere (A), often 'amp' for short. A current meter is an ammeter – a shortened form of 'ampere meter' or 'amp meter'. Small currents are often measured in milliamps (mA). You can say that 0.250 A passes through a 250 mA bulb. That means the same thing.

It does not matter where you put the ammeter in the circuit: it can be to the left or the right of the bulb. The same amount of charge goes into the bulb on one side as comes out on the other. The current is the same at all points throughout the circuit (figure 4).

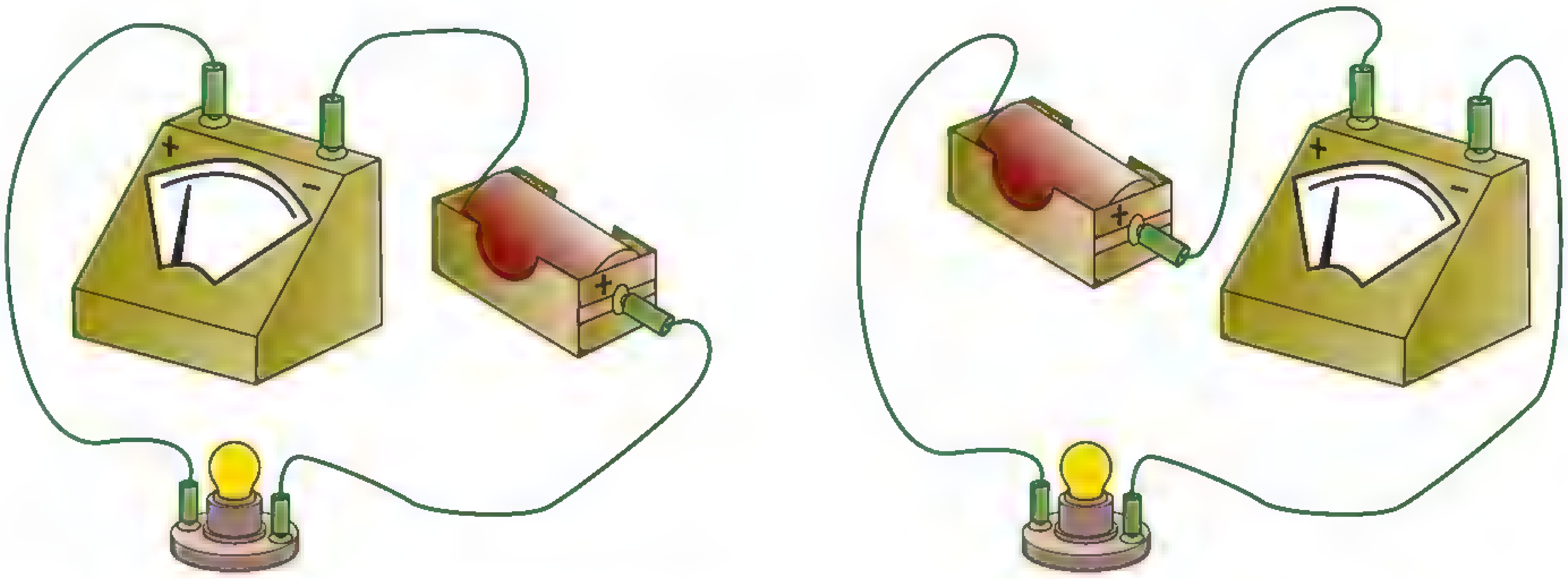


figure 4 Two ways of measuring the size of the current.

Practice the concepts using the *Flash cards*.

EXTRA LED LIGHTS

An LED is a type of bulb that is used in all kinds of lighting. One characteristic of an LED is that current can only flow through it in one direction. If you try to do it the other way round, no current flows and the LED does not give off any light. So you have to be careful to connect LEDs up the right way round: the longer connecting leg has to be connected to the positive side of the battery (figure 5).

figure 5 A close-up of an LED.

LED stands for 'light-emitting diode'. That is the name of the small electronic component that actually produces the light. If you have an LED with a clear plastic sheath, you can see the actual diode if you look carefully. The plastic sheath protects the LED and the connecting wires. The rounded top of the LED also helps bundle the light from the diode into a beam.

Bike lights almost always use LEDs now (figure 6). The advantage of LEDs is that they use electrical energy very efficiently: They use about 90% less electrical energy than incandescent bulbs. They give off a lot of light for just a small amount of electricity. On top of that, LEDs last a long time and they are also shock-resistant.

figure 6 A rear bike light with five LEDs.

COURSE MATERIAL

1

Answer the following questions.

a What do you have to do in order to light a small bulb using a battery?

b Which group of substances are all good conductors of electricity?

c What do you call substances that do not allow electrical currents to pass through them (or only very poorly)?

d Jasmine has made an electric circuit where she can turn a bulb on and off. List the three components (other than the bulb) that Jasmine must have included in the circuit.

2

Complete:

a An electrical current consists of .... that is moving through .... materials.

b You can use an .... to measure the current in a circuit.

c The magnitude of the current is measured in .... , abbreviated to the letter ....

3

Which of these substances are conductors?
glass – iron – copper – air – plastic – rubber

IN PRACTICE

4

Explain how the fairground game in figure 7 works.
Use the phrases 'open circuit' and 'closed circuit' in your explanation.

figure 7 If your hand isn't steady, the bell will ring.

5 Figure 8 shows you three photos of an ammeter. Look to see which measurement range has been selected in each photo (you can see that from the red wire).
Read off the currents that the three meters are showing and write them down.
See the skills section on *Working with an ammeter.*

ammeter a: .... A

ammeter b: .... A

ammeter c: .... A

figure 8 What currents are the three ammeters showing?

ammeter a

ammeter b

ammeter c

If you need a bit more practice reading ammeters, go to the *Skills Trainer* in Section 1 (Making a circuit).

6 Rachel is measuring the current between the positive terminal of a battery and a bulb (figure 9).

a What current is the ammeter reading? .... A

b Rachel then measures the current between the bulb and the negative terminal of the battery.
What can you say about the current that she measures now?
- ○ A It is greater than what she just measured in Exercise 6a.
- ○ B It is the same as what she just measured in Exercise 6a.
- ○ C It is less than what she just measured in Exercise 6a.

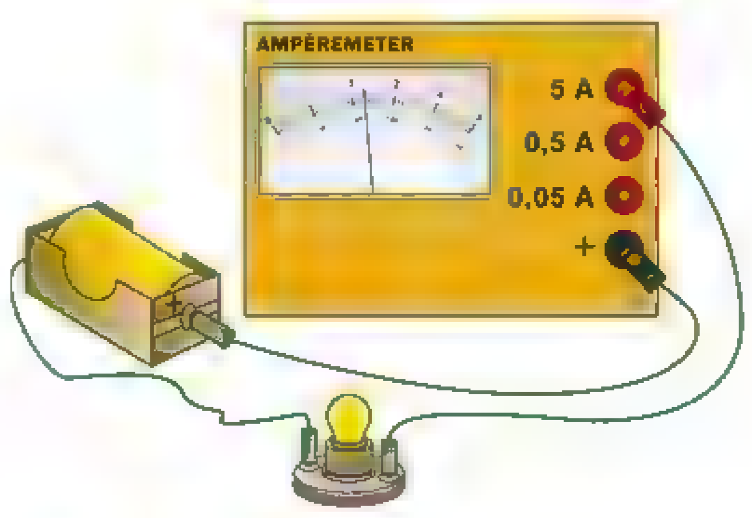


figure 9 Rachel's experimental setup.

7 Calculate:

a 37 mA	= .... A	**f** 950 mA	= .... A
b 452 mA	= .... A	**g** 0.072 A	= .... mA
c 0.250 A	= .... mA	**h** 0.008 A	= .... mA
d 0.032 A	= .... mA	**i** 1282 mA	= .... A
e 3 mA	= .... A	**j** 0.125 A	= .... mA

If you need a bit more practice converting between amps and milliamps, go to the *Skills Trainer* in Section 3 (Circuits).

8 When you turn a light switch to the OFF position, the circuit is broken. There is then only air between the conducting parts of the switch.
Explain how this lets you conclude whether air is a conductor or an insulator.

9 Luke wants to investigate whether tap water conducts electricity.
Explain how he can do an experiment to find this out. Sketch of his experimental setup.

10 Flora finds an article on a website about how you can easily make your own door alarm.
The guide is shown in figure 10.
Explain how the circuit works.

figure 10 Making your own burglar alarm.

★ 11 Figure 11 shows you a circuit with a bulb, a battery and a switch. All the metal parts of the electrical circuit are connected to each other.
Explain why the bulb is not lit.

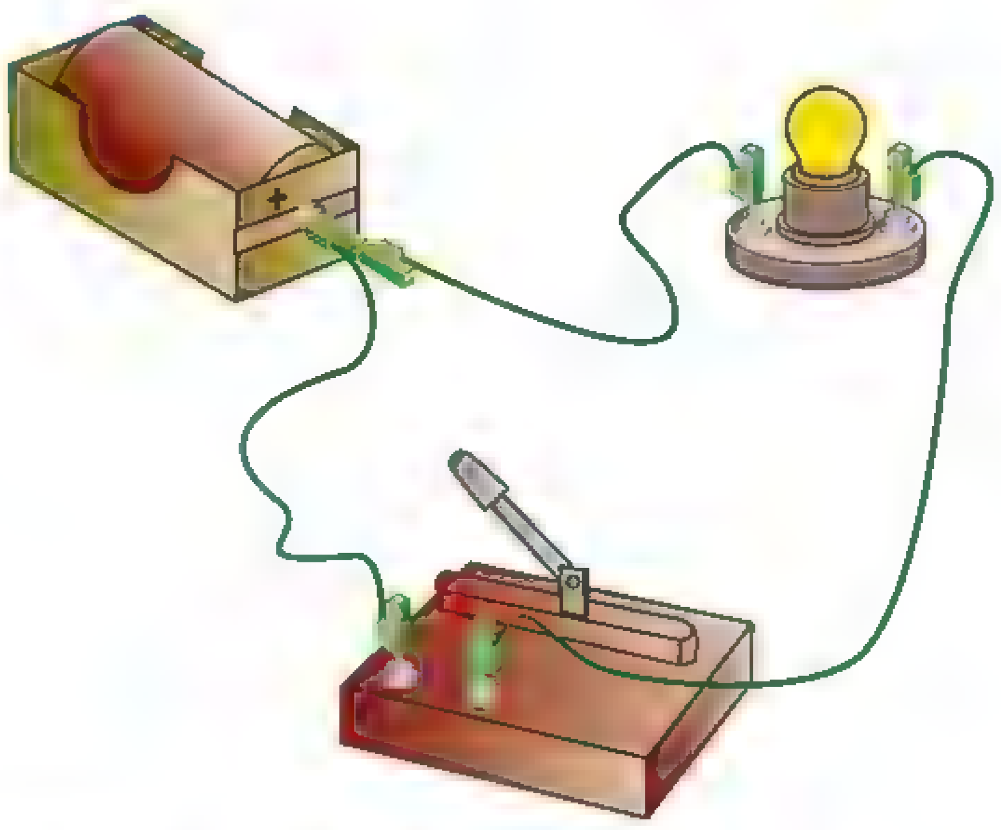


figure 11 Why is the bulb not lit?

Test what you know with *Test yourself*.

EXTRA LED LIGHTS

12 Beth has connected an LED up to a battery (figure 12). The LED is not lit. Beth is sure that there is nothing wrong with either the battery or the LED and that the wires are securely attached.

a What is probably wrong?

b Beth then makes a circuit with five red LEDs. When she connects up the battery, all of the LEDs light up. If any of the LEDs break, they all go out.
Draw the circuit that Beth has made in figure 13.

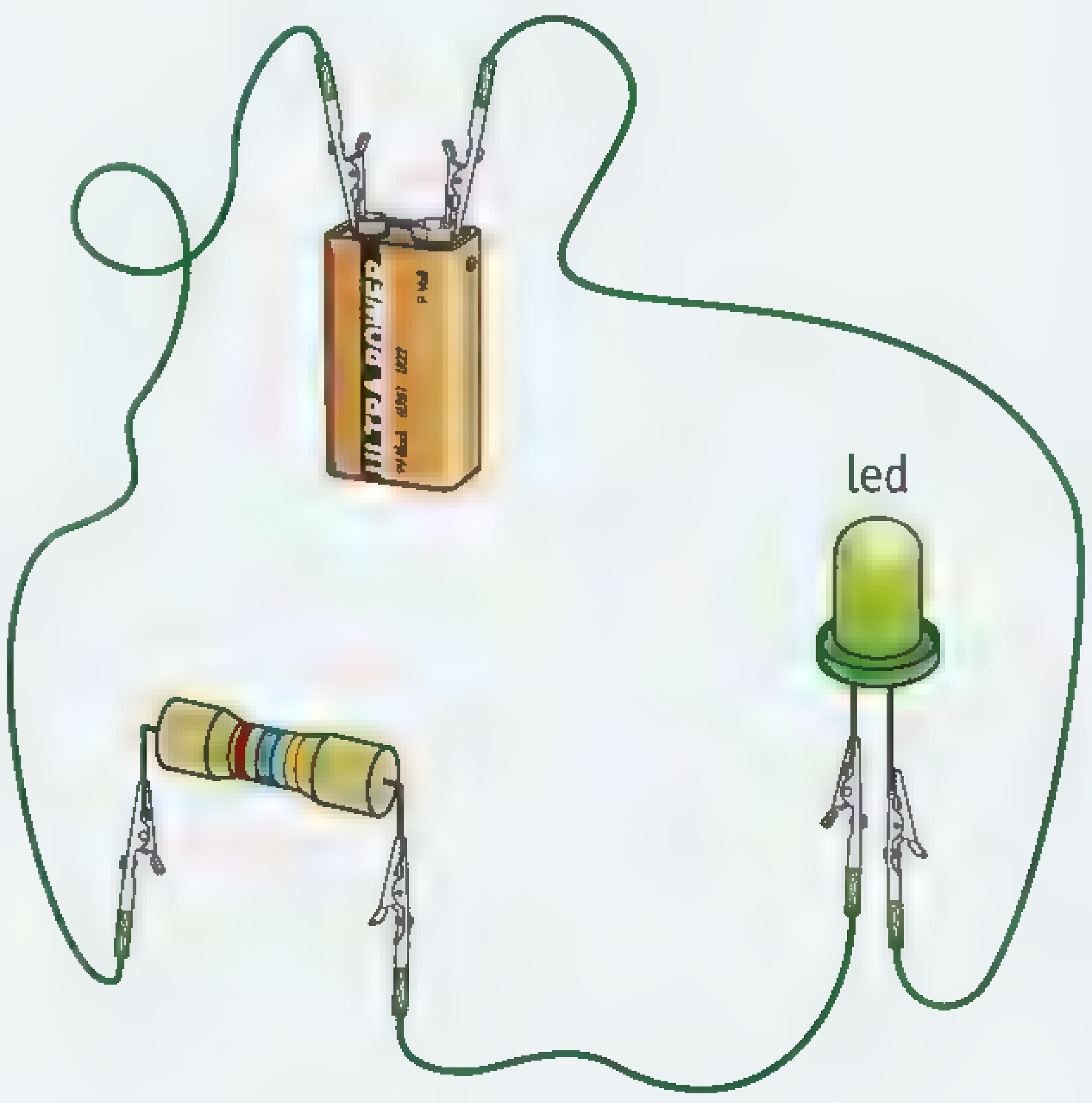


figure 12 Beth's circuit.

figure 13 The electrical circuit with LEDs.

13 List two benefits and one disadvantage of LEDs.

2 Voltage sources

LEARNING OBJECTIVES

4.2.1 You can list a number of voltage sources.
4.2.2 You can explain what voltage is.
4.2.3 You can describe how you measure voltages.
4.2.4 You can explain what current is.
4.2.5 You can calculate the voltage when you connect batteries in series.
4.2.6 You can state whether various common voltage sources are safe or unsafe.
4.2.7 You can describe what you need if appliances that use lower voltages are to be plugged into a mains socket.
EXTRA 4.2.8 You can explain how you can reduce the harmful effects of using batteries.

TAXONOMY	LEARNING OBJECTIVES AND EXERCISES								
	4.2.1	4.2.2	4.2.3	4.2.4	4.2.5	4.2.6	4.2.7	4.2.8	4.1.1*	4.1.2*
Remembering	1a, 3c	3b	3a	2ab	1b	1c, 3d	1d	9, 11cd		
Understanding			4		7c		8c	10abc, 11ab	7ab	8a
Using					5abc, 6abcd, 7d, 8d				8b	
Analysing									8e	

* You can find this learning objective in an earlier section.

To create a circuit, you need a voltage source. Commonly used voltage sources include batteries and dynamos. The panels with solar cells that you often see on roofs are also voltage sources.

VOLTAGE

A battery always states what **voltage** it supplies. For example 1.5 volts, 9 volts or 12 volts. You can check the stated voltage with a **voltmeter.** To do that, you need to connect the meter across the positive and negative terminals of the battery. Because the voltage is measured in volts (V), a meter for measuring a voltage is called a voltmeter.

But what exactly is a voltage? You can compare electrical voltage to the tension in an inflated balloon. If you inflate the balloon a lot, its skin becomes more tense. You can feel that if you press on the balloon: the rubber is stretched tight. If you only inflate a balloon half full, the tension is much lower. The rubber then gives way easily (figure 1).

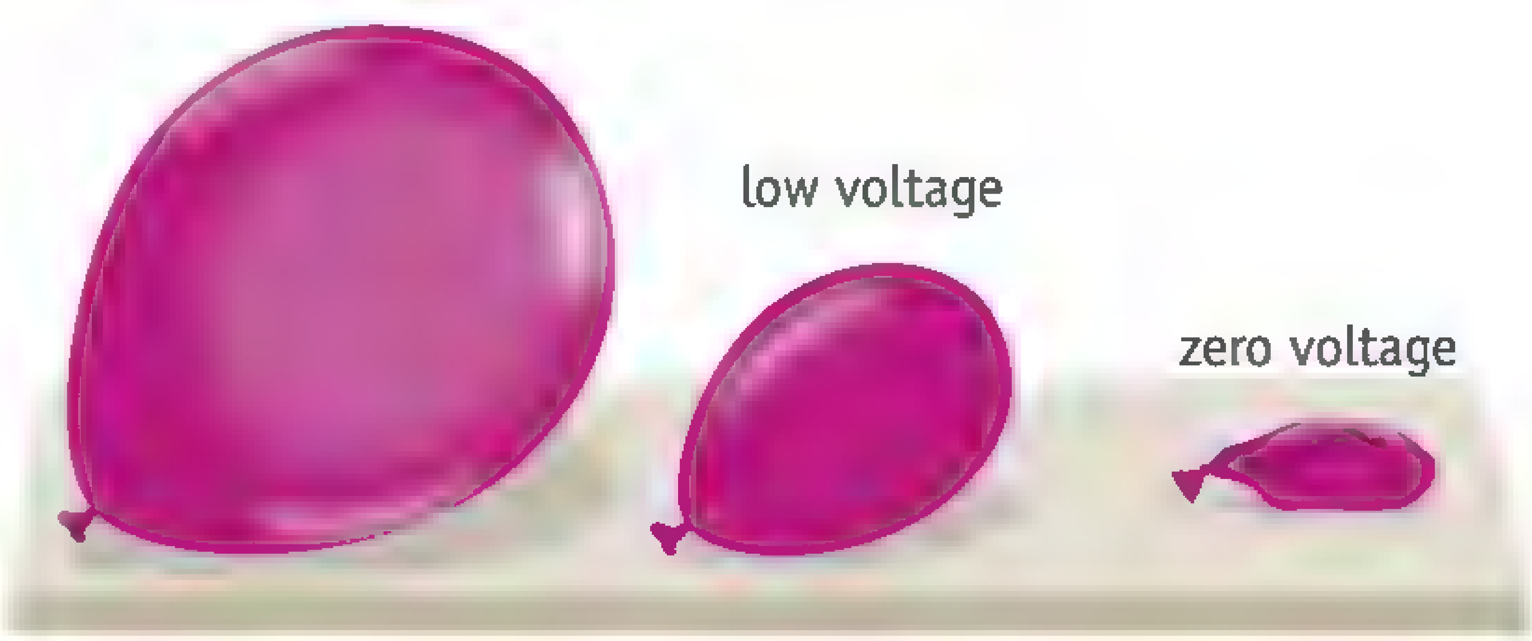


figure 1 The more air there is in the balloon, the greater the tension.

If you open the balloon's neck (which is acting as a valve) just a little bit, the air starts to flow out. This reduces the tension in the balloon. The current (the amount of air that flow out from an inflated balloon every second) also falls. After a little while, the tension is completely gone and no more air flows out of the balloon.

There is an electrical component that behaves just like a balloon: a capacitor (figure 2). You can charge up a capacitor by storing charge in it. The voltage rises until it cannot take any more charge. When you then let the charge out, the voltage gets reduced, quickly at first and then more and more slowly (figure 3).

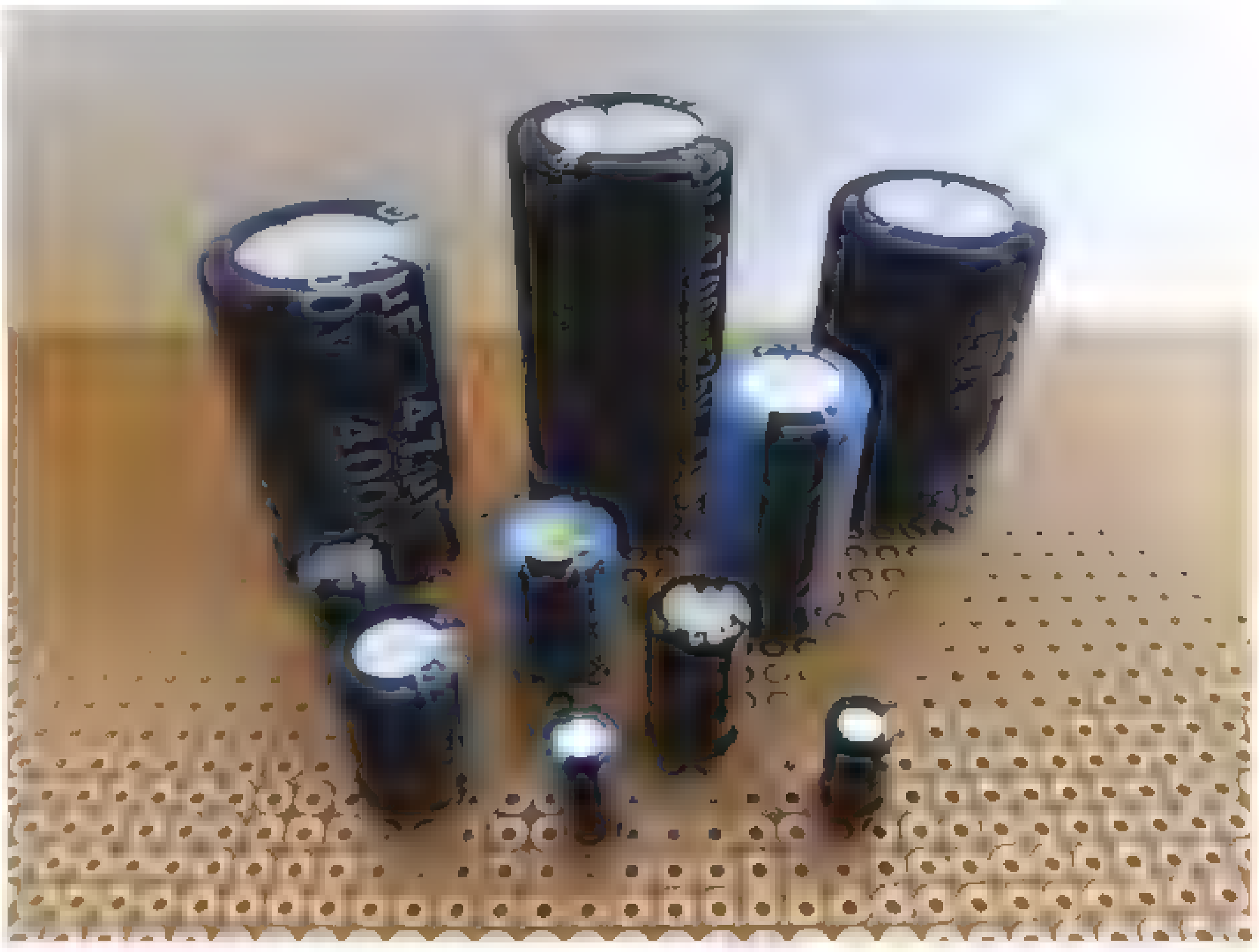


figure 2 Capacitors come in many sizes.

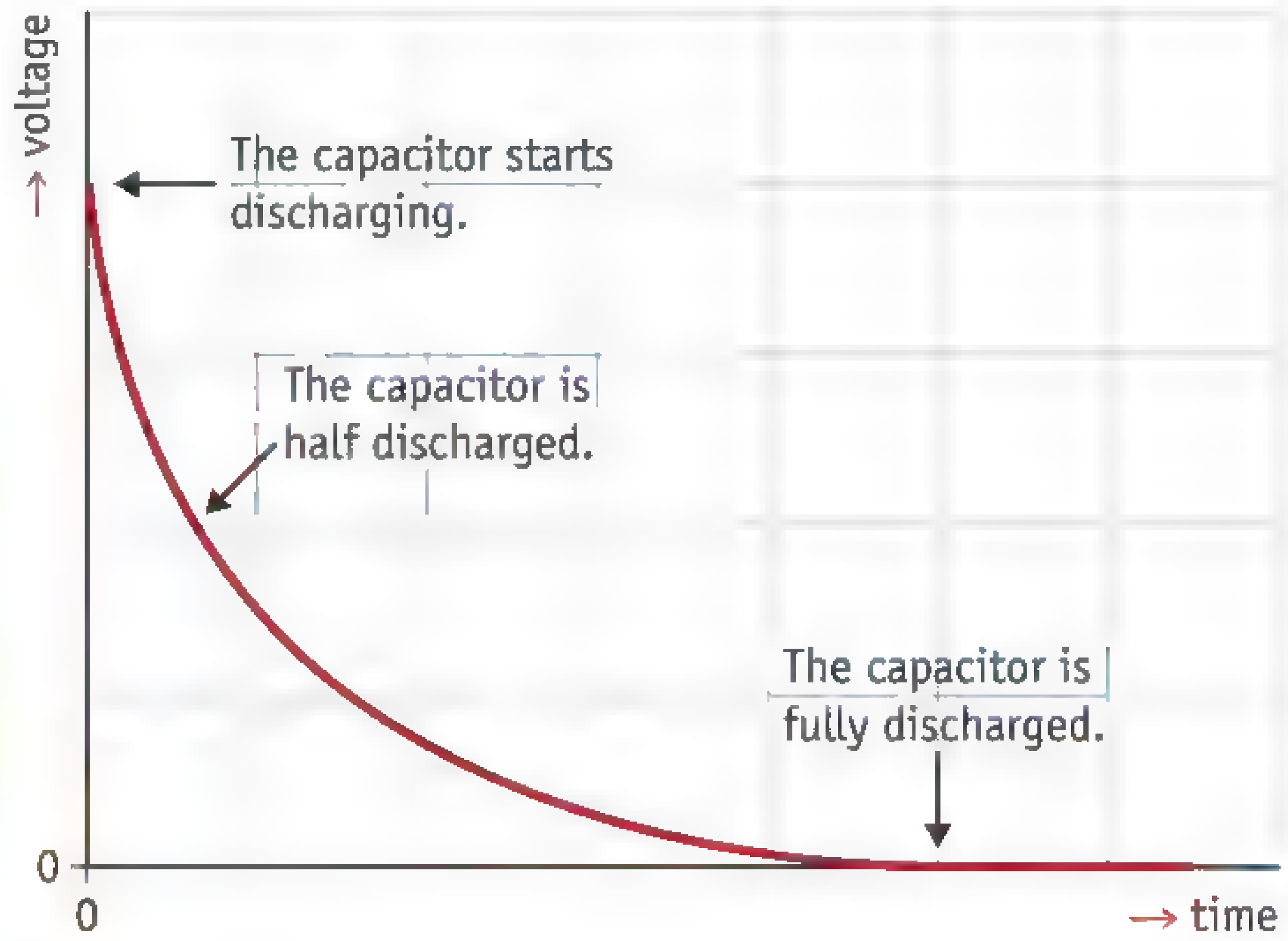


figure 3 This is how a capacitor discharges.

Capacitors are often used to protect components in electronics against rapid voltage changes. But they are not suitable for devices to run on. This is because a capacitor does not provide a constant voltage. If you connect a bulb to a capacitor, the light will keep getting dimmer and go out very quickly. That isn't what you want!

BATTERIES

Batteries do supply a constant voltage (figure 4). That is why they are called **voltage sources.** When you use a battery, charge flows from the battery into the circuit continuously. However, the battery's voltage does not change. This is because a battery continually releases more charge. This makes sure that the voltage is kept at a constant level.

figure 4 Various types of batteries: each voltage source has its own specific voltage.

The charge that flows out of a battery comes from the substances in the battery. These substances slowly get used up in the process. When they have almost run out, they can no longer produce enough charge to keep the voltage at a constant level. We then say that the battery is almost 'flat' or 'dead'.

You can only use normal batteries up once. They have to be thrown away after they have been used up. But there are also **rechargeable batteries.** You can recharge them by passing a current through them in the opposite direction. This reverses the changes inside the battery. The original substances are recreated. In normal batteries, the changes cannot be reversed.

CONNECTING BATTERIES TOGETHER

You often need more than a single battery to obtain the right voltage. For the remote control in figure 5, for example, you need two 1.5 V batteries. You have to connect the batteries up in series. That means that you connect the positive terminal of one battery to the negative terminal of the other battery. They will then together provide a voltage of 3.0 V.

figure 5 This remote control takes two 1.5 V batteries.

If you connect four 1.5 V batteries in series, together they will provide a voltage of 6.0 V. The general rule is that

> If you connect batteries in series, you can add their voltages together.

If you accidentally connect one of the four batteries the wrong way round, it will work against the other three. The total voltage will then be 1.5 + 1.5 + 1.5 – 1.5 = 3.0 V.

SAFE AND UNSAFE VOLTAGES

The **mains voltage** in the Netherlands is 230 V. This is the voltage of an electrical socket. Voltages this high are definitely quite hazardous. If you touch a conductor that is at 230 V, you will at the very least get an unpleasant shock. Under unfavourable circumstances, it could even kill you. Devices that operate on 230 V therefore need to be properly insulated so that you cannot touch components that are 'live' at a high voltage.

The voltage that a battery supplies is far less than 230 V. This kind of low voltage is not dangerous. In fact, if you touch the terminals of a battery, you do not feel anything! A value of 24 V is often used as a safe limit. Battery-operated devices are well below that, so you do not need to be afraid that a mobile phone or a cordless drill will give you a shock.

Many devices operate on lower voltages than 230 V. If you still want to be able to plug them into a mains socket, you need a **transformer.** This is a device that converts the mains voltage down to a low voltage. The adapter that you use to recharge a mobile phone contains a transformer that converts the mains voltage of 230 V to a voltage of 5 V.

Practice the concepts using the *Flash cards*.

EXTRA BATTERIES AND THE ENVIRONMENT

Batteries often used to contain cadmium or mercury. Those elements are highly toxic and are therefore no longer allowed to be used in batteries. Even so, batteries do still contain substances that are harmful to the environment. This is why batteries should be treated as small-scale chemical waste items (figure 6). This applies to both rechargeable and non-rechargeable batteries.

Rechargeable batteries are less damaging for the environment than normal ones because they last much longer. You can recharge this type of battery hundreds of times. This does little to no damage to the environment, especially if you use renewable electricity (from solar panels, for instance). At some point, though, even rechargeable batteries reach the end of their lifespan.

Discarded batteries contain valuable substances such as nickel, copper and cobalt. There are companies that extract those substances from the batteries so that they can be reused. This is called recycling. Recycling substances lets you reduce waste and at the same time reduce the consumption of raw materials.

figure 6 Batteries count as small-scale chemical waste.

COURSE MATERIAL

1 Answer the following questions.

- **a** Which three types of voltage sources are mentioned in this section?
- **b** How can you calculate the voltage of four batteries connected in series?
- **c** Why do devices that operate on 230 V need to be properly insulated?
- **d** What do you need for converting the mains voltage down to a lower voltage?

2

- **a** Why is a capacitor not suitable as the voltage source for a flashlight?
- **b** If you connect batteries in series, you can add their *voltages / currents* together.

3 Complete:

- **a** You can use a .... to measure the voltage that a voltage source provides.
- **b** The size of the voltage is measured in ...., abbreviated to the letter ....
- **c** The .... (the voltage of the electrical sockets) in the Netherlands is 230 V.
- **d** A useful rule of thumb is that voltages of up to .... V do not present a risk.

IN PRACTICE

4

Figure 7 shows you three photos of a voltmeter. Look to see which measurement range has been selected in each photo (you can tell that from the red wire).
Read off the voltages that the three meters are showing.
See the skills section on *Working with a voltmeter.*

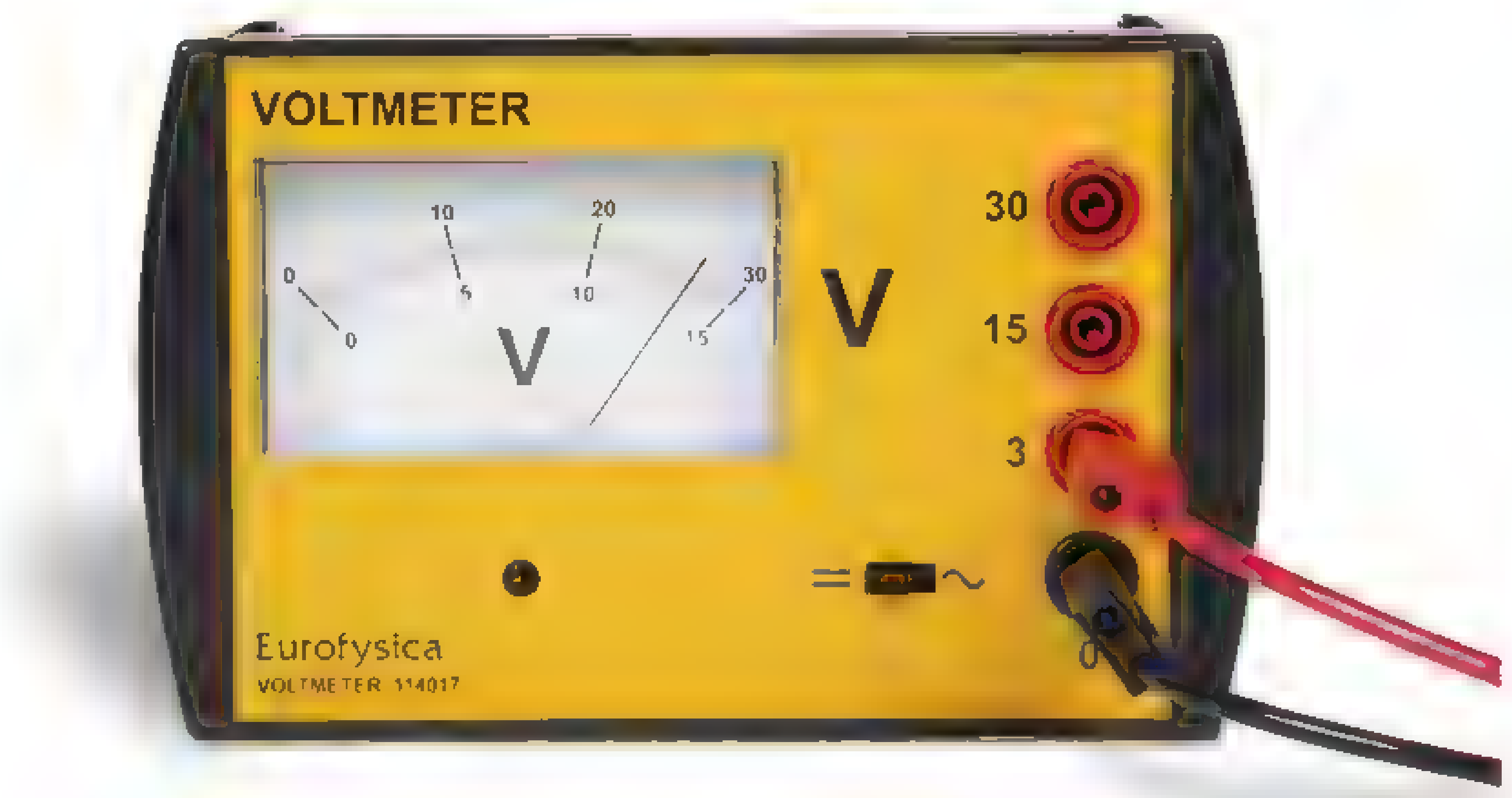
voltmeter a: V

voltmeter b: V

voltmeter c: V

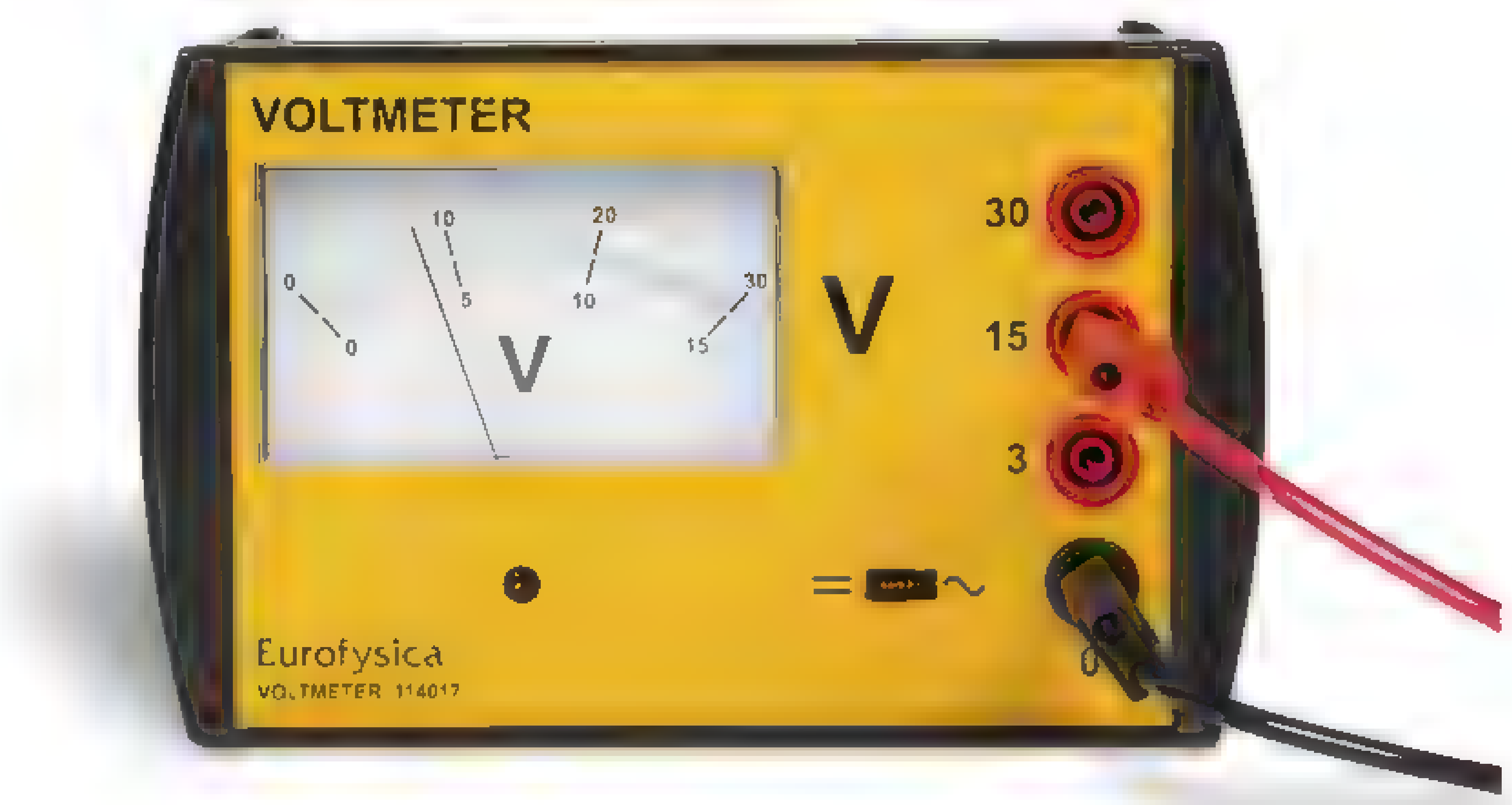
If you need a bit more practice reading voltmeters, go to the *Skills Trainer* in Section 2 (Voltage sources).

figure 7 What voltages are the three voltmeters reading?



voltmeter a

voltmeter b



voltmeter c

5

Figure 8 shows three voltmeters and batteries. The batteries are connected in series inside the battery holder.

a Make a drawing next to point a showing how you should connect the voltmeter to read 1.2 V.

b Make a drawing next to point b showing how you should connect the voltmeter to read 2.4 V.

c Make a drawing next to point c showing how you should connect the voltmeter to read 3.6 V.

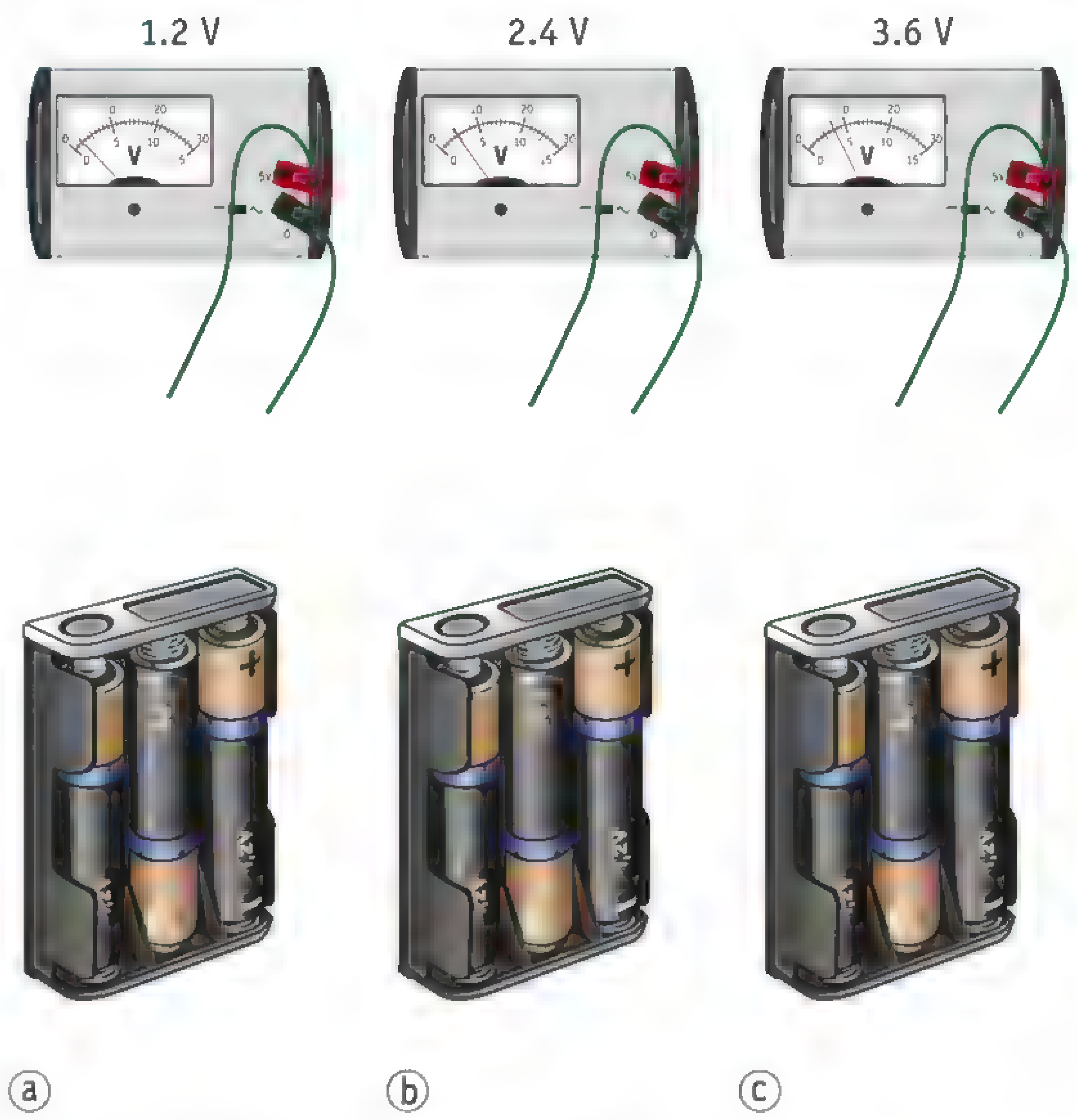


figure 8 Connecting up three different voltmeters.

6

Figure 9 shows 1.5 V batteries are combined in various ways. What is the voltage delivered by the combination of batteries in:

a diagram a? V

b diagram b? V

c diagram c? V

d diagram d? V

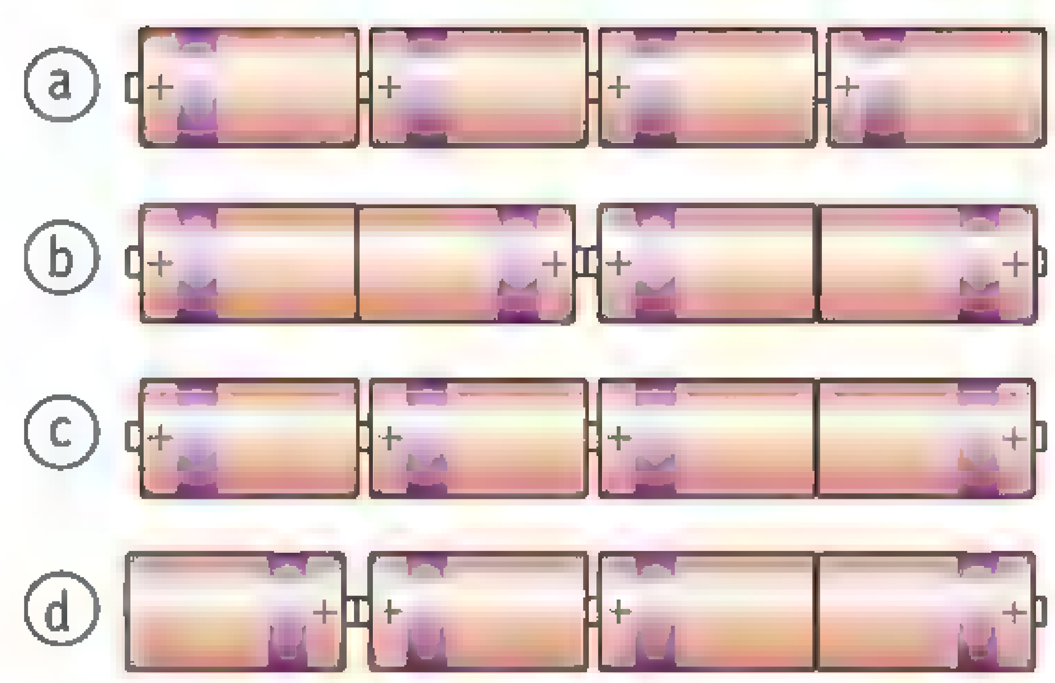


figure 9 Four combinations of batteries.

7

Figure 10 shows you a picture from the manual for a set of bathroom scales. The scales work on four AA batteries of 1.5 V.

a Why is the plate on the right-hand side of the batteries made of a conducting material?

b Is the spring on the left also made of a conducting material? Explain your answer.

c How are the batteries connected, if you fit them in the compartment correctly?

d What is the voltage that the four batteries provide together?

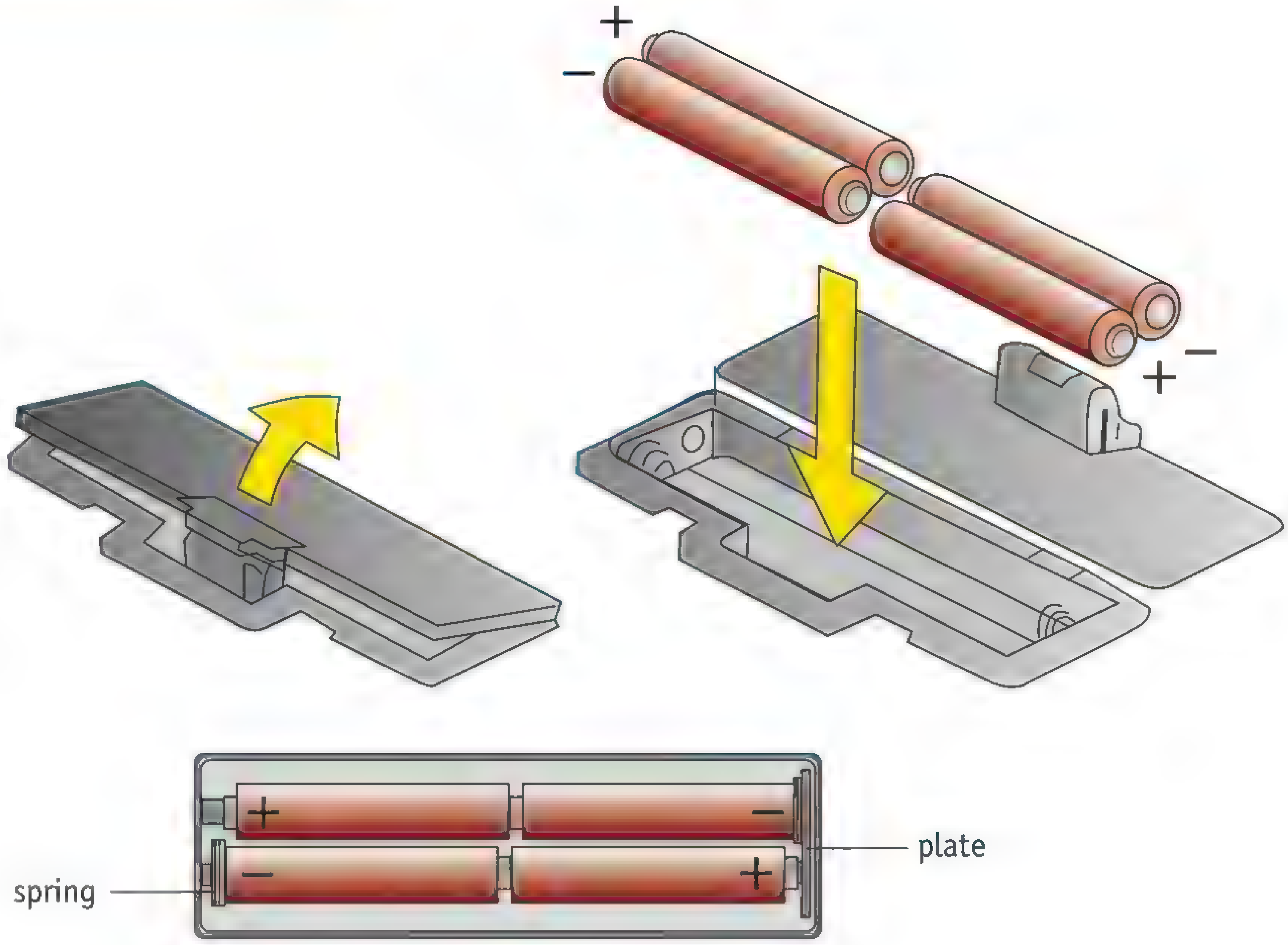


figure 10 This is how the batteries have to be inserted in the scales.

★ 8

Electrified wire at a voltage of 10,000 V is often used to partition off fields. Figure 11 shows a schematic drawing of an electric fence. Cattle get used to the electric fence pretty quickly and learn that they have to avoid the wires. It takes a lot longer with horses before they get used to the electrified wires.

a An electric fence is an example of a circuit. Name the various parts of the circuit.

b The voltage source applies short pulses of voltage to the wires of the electric fence. What happens when an animal touches the electrified wires?

The circuit is then *open / closed*. As a result, the animal gets an ....

c The high-voltage source has a battery pack that supplies a voltage of 12 V. In addition to the battery, what other electronic component does a high-voltage source have?

d The battery pack has six identical batteries that are connected in series. Calculate the voltage of a single battery.

e It is important that no tall grass or shrubs are allowed to grow under the electric fence. Explain why this is important.

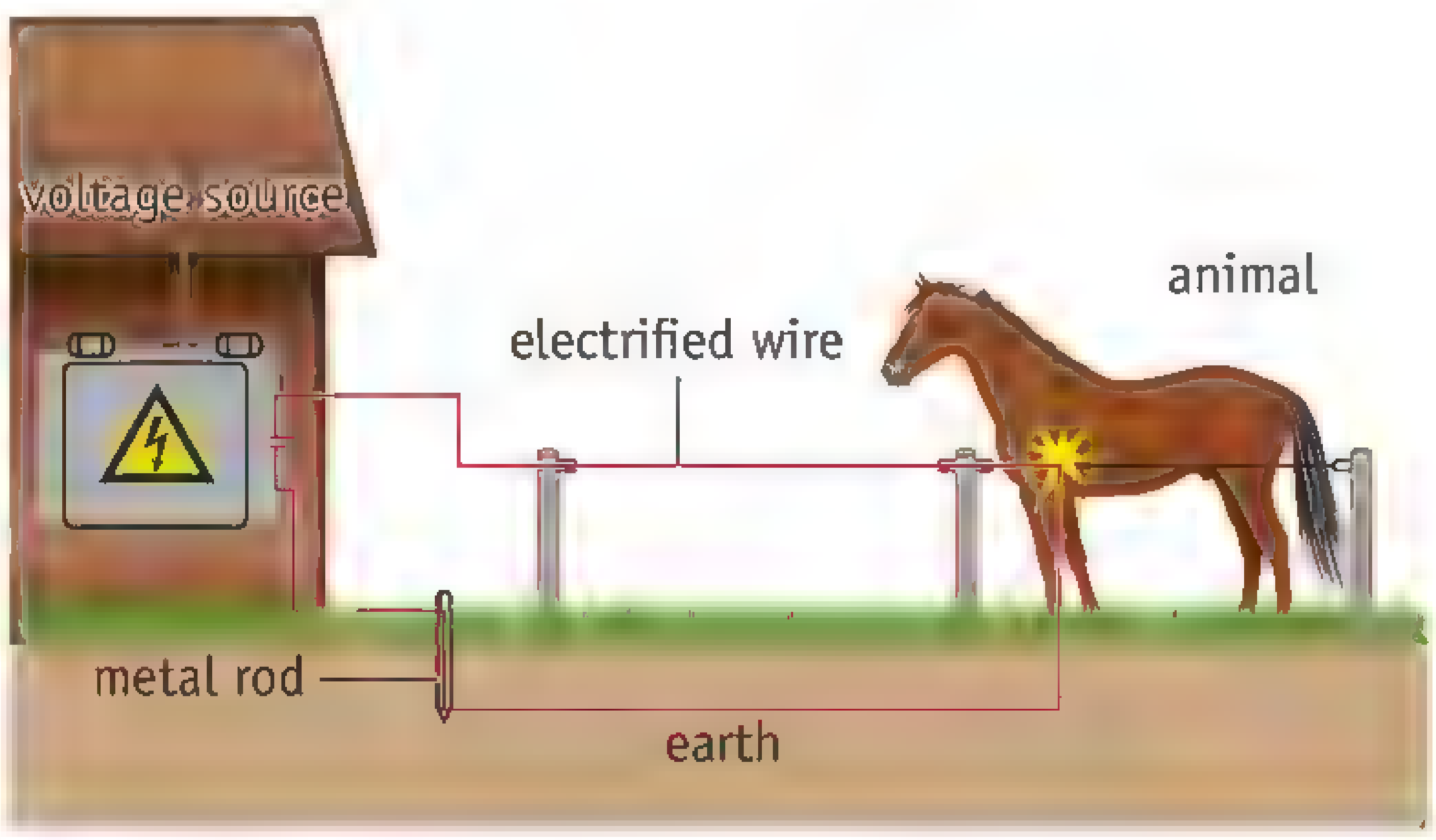


figure 11 An electrified fencing system.

Test what you know with *Test yourself*.

EXTRA BATTERIES AND THE ENVIRONMENT

9 Sometimes someone will say “This battery is dead” or “This battery is flat.” The battery was never alive or inflated in the first place, of course.
So what do we mean when we say that a battery is ‘fresh’ or ‘dead’?

10 Rechargeable batteries are more expensive than non-rechargeable ones.

a Explain why rechargeable batteries can nevertheless work out as cheaper overall.
b Explain why rechargeable batteries are also less damaging for the environment.
c Non-rechargeable batteries are bad for the environment, but so are rechargeable ones.
Why are rechargeable batteries also bad for the environment?

11 Read the text in figure 12.

a Even if you have taken the battery out of the card, it is not a good idea to dispose of it with the waste paper. Explain why.
b What type of waste are the batteries from the greeting card?
c Write down three valuable metals that can be reclaimed from batteries.
d What is the term for reclaiming raw materials from used batteries?

Batteries in greeting cards: don’t forget them

Happy birthday to you!, Jingle bells, jingle bells, jingle all the way!: two famous songs that may be heard coming from a greeting card when you open it. A winner in sales terms: millions of them are sold every year, not only in the form of cards but also as small gift boxes. They eventually end up in the stack of waste paper.

After: www.bebat.be

figure 12 A musical greeting card.

3 Circuits

LEARNING OBJECTIVES

4.3.1 You can list the symbols that you use for making circuit diagrams.
4.3.2 You can explain the difference between a series circuit and a parallel circuit.
4.3.3 You can draw a circuit diagram for a simple series circuit or parallel circuit.
4.3.4 You can explain why electrical appliances are almost always connected in parallel.
4.3.5 You can work out the current in a circuit.
EXTRA 4.3.6 You can describe what a mixed circuit is.

TAXONOMY	LEARNING OBJECTIVES AND EXERCISES						
	4.3.1	4.3.2	4.3.3	4.3.4	4.3.5	4.3.6	4.2.5*
Remembering	2abcd	1ab		1c	1d		
Understanding		6, 8abc		5abc	4ac	10abcd, 11ab	4b
Using		7ab	3		9abcd	10e, 11d	
Analysing						11c	

* You can find this learning objective in an earlier section.

You can connect bulbs, switches, wires and voltage sources together in various ways. Or to put it differently, you can make a variety of different circuits with them. A circuit will always contain one or more closed loops through which electricity can flow.

DRAWING CIRCUITS

EXP 3+4

If you want to explain to someone what a particular circuit looks like, the best way is to use a drawing. Special symbols have been thought up to let you make clear circuit drawings (figure 1). This type of drawing is called a **circuit diagram**.

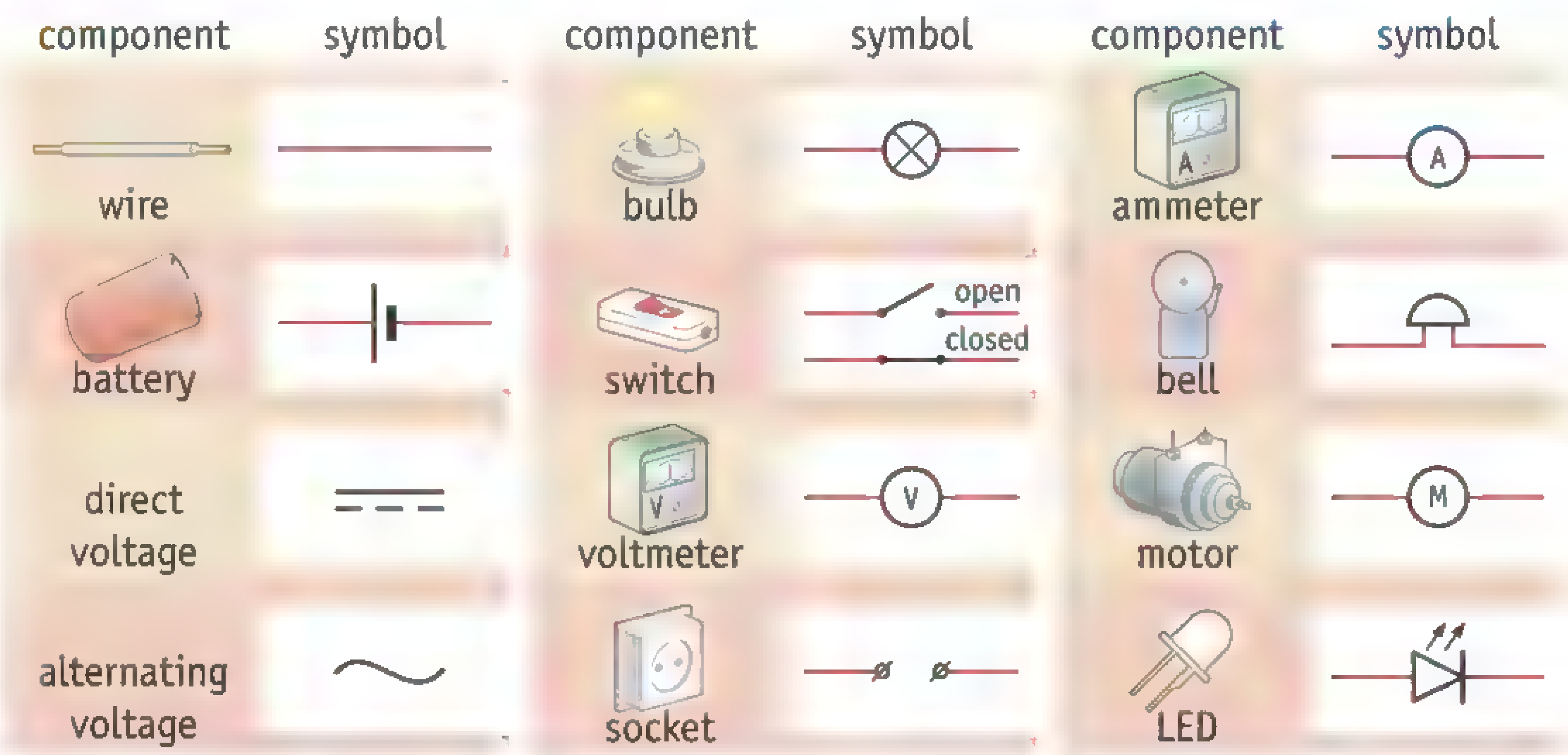


figure 1 Symbols for circuit diagrams.

Circuit diagrams are indispensable for experiments with electricity. The diagram shows you what components you need and how to connect them together. The book shows circuit diagrams for a lot of the experiments. Sometimes you have to draw a circuit diagram yourself. After you have collected together all the components, you build the circuit using the diagram.

Circuit diagrams are also used when developing electrical and electronic devices. First, the design team makes a circuit diagram on which all the components and their connections are represented schematically. Once that diagram has been approved, the team works out the best (and cheapest) way of putting the circuit together.

SERIES CIRCUITS

Figure 2 shows you a **series circuit** with three bulbs. A series circuit has no branches: there is just one current loop. If any one of the bulbs dies, the circuit is broken and so all the bulbs go out. Connecting bulbs in series is therefore not very practical. You want the other bulbs to keep working if one bulb dies.

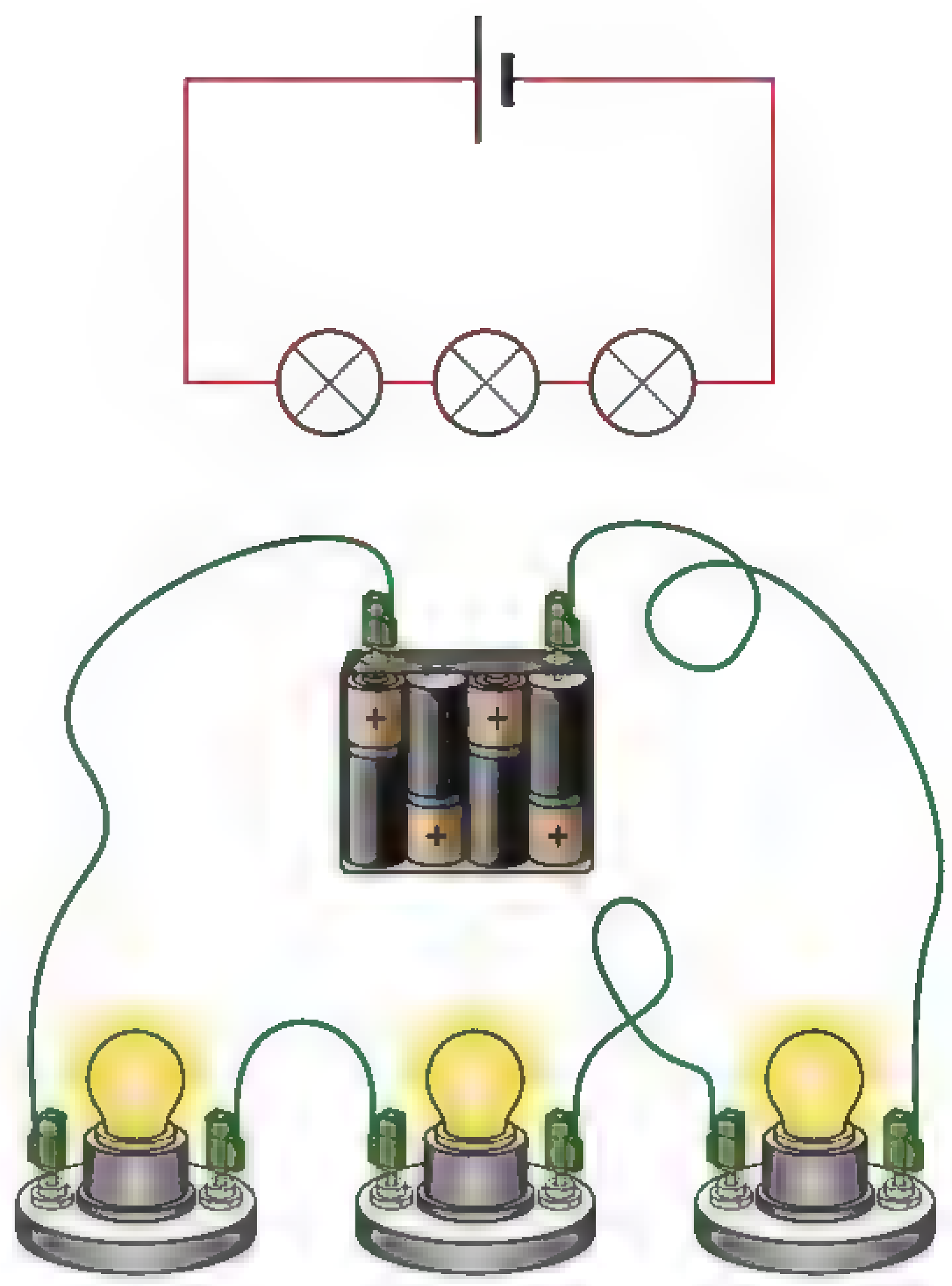


figure 2 A series circuit with three bulbs.

However, you do want a switch to be connected up in series with the device that is to be switched on and off. You use a light switch to turn a bulb on or off. When you turn the switch to OFF, you are opening the circuit and so the bulb is turned off. When you turn the switch to ON, you are closing the circuit and so the bulb is turned back on.

- In an open circuit, the switch is open and the bulb is off (figure 3).
- In a closed circuit, the switch is closed and the bulb is on (figure 4).

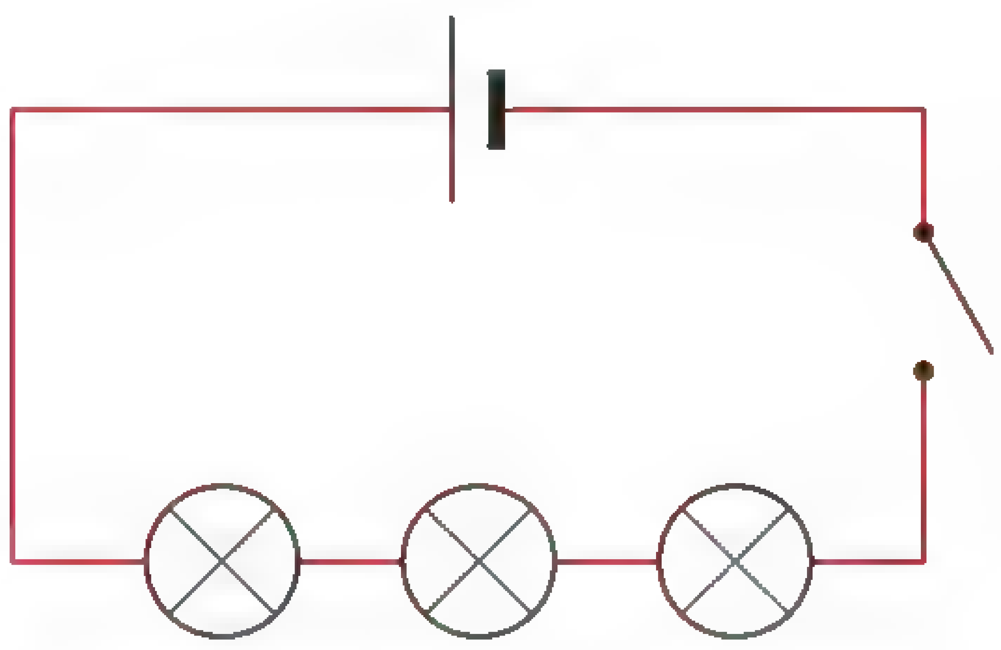


figure 3 An open circuit: the bulbs are off.

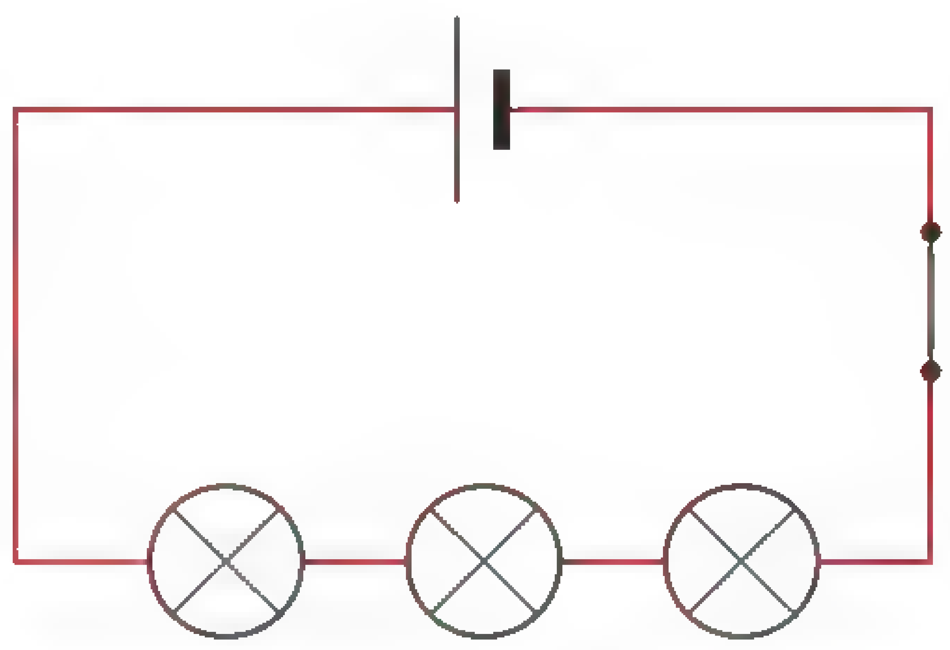


figure 4 A closed circuit: the bulbs are on.

The current in a series circuit is equally strong throughout. It doesn't matter where you measure the current: between the battery and the first bulb, between the first bulb and the second bulb, between the second bulb and the third bulb, or between the third bulb and the battery. The charge that flows into a bulb also flows out of it. You will always measure the same value.

The voltage that the battery provides will be split across the three bulbs. If you have used three identical bulbs, each of them will receive a third of the **source voltage** (the voltage supplied by the battery). You can check that by measuring the voltage across a single bulb, as drawn out for you in figure 5.

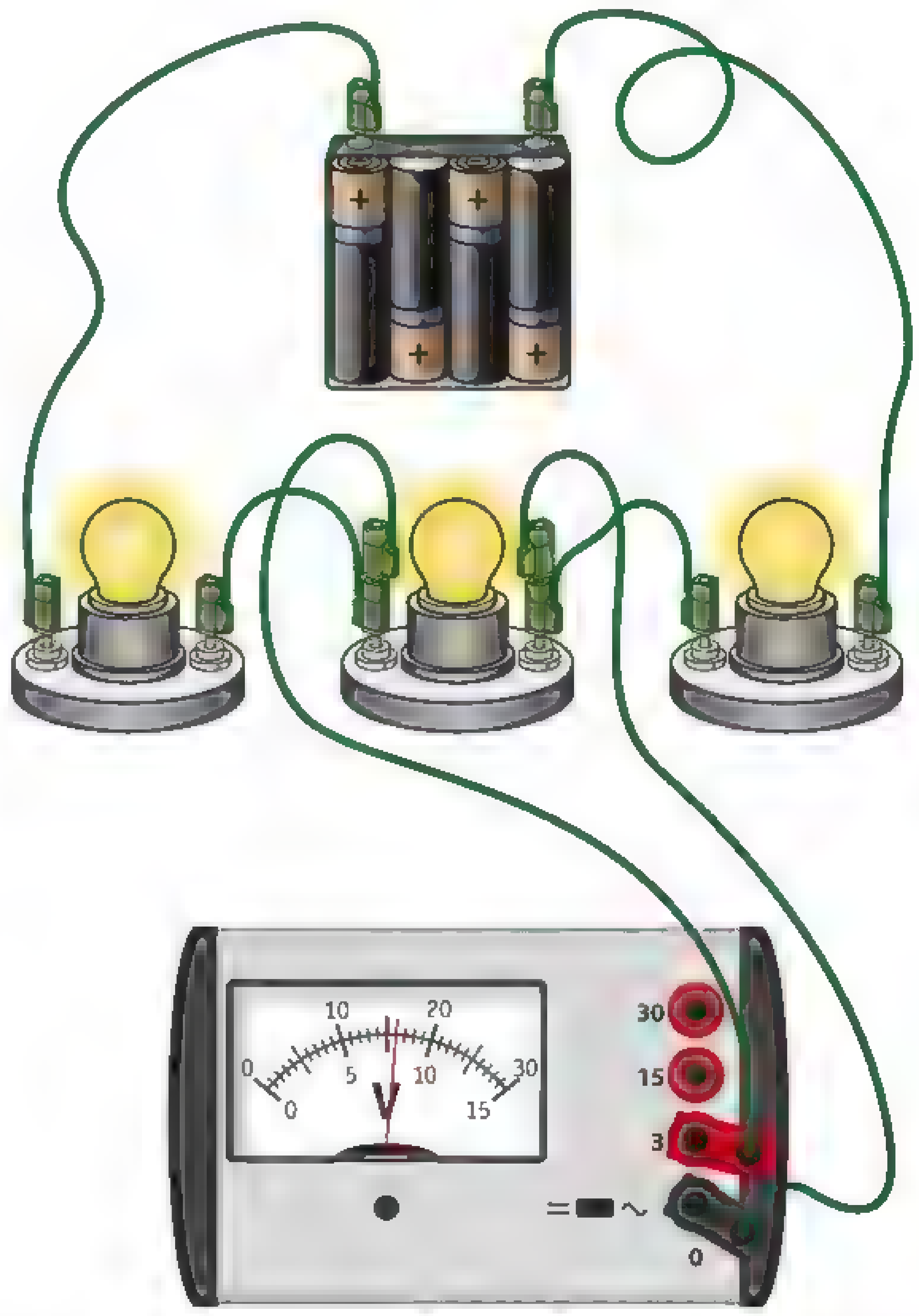


figure 5 Measuring the voltage across a single bulb.

PARALLEL CIRCUITS

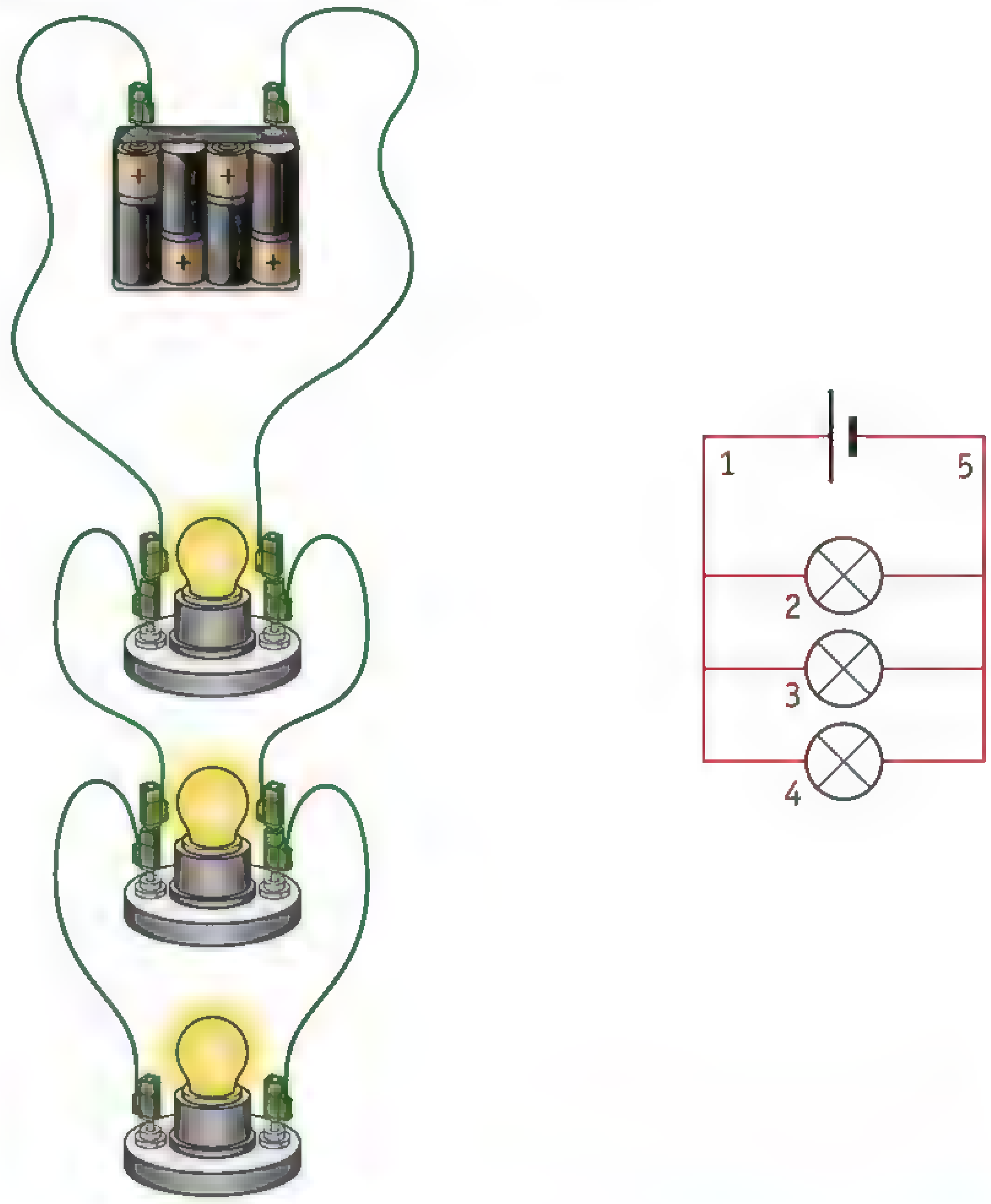
EXP. 7

Electrical devices are almost always connected in parallel. This has three benefits:

1 Each device can then be switched on and off with its own switch.
2 If one device breaks, the others can continue to operate.
3 Each device receives the full voltage of the voltage source.

Figure 6 shows you a **parallel circuit** with three identical bulbs. The circuit is branched into three. Each bulb is directly connected to the source voltage. The parallel circuit therefore comprises three circuit loops. Each of these circuits can be opened and closed independently if you put a switch in each branch.

figure 6 A parallel circuit with three bulbs.



The current splits at the point in a parallel circuit where the circuit branches. The current in figure 6 is split into three. The current in the unbranched parts (at 1 and 5) is called the total current. The current in each of the branches (at 2, 3 and 4) is one third of the **total current**. The current in a parallel circuit is therefore not the same everywhere, unlike the situation in a series circuit.

Practice the concepts using the *Flash cards*.

EXTRA MIXED CIRCUITS

EXP. 8

In a mixed circuit, some components are connected in series and others in parallel. Figure 7 shows an example of this kind of circuit: bulbs 2 and 3 are connected in parallel with one another but are in series with bulb 1.

A mixed circuit will behave differently to either a series circuit or a parallel circuit. If you unscrew bulb 1, bulbs 2 and 3 will also go out. There is no longer a closed circuit then. But if you unscrew bulb 2, bulbs 1 and 3 will stay lit. This is because there is then still a closed circuit through them.

You can often work out what the current is at various places in a mixed circuit. Bulb 1 will for example be brighter than bulbs 2 and 3. Think about it: all the current that goes through bulb 2 plus all the current that goes through bulb 3 has to go through bulb 1 too. There is as much current going through bulb 1 as there is going through bulbs 2 and 3 together.

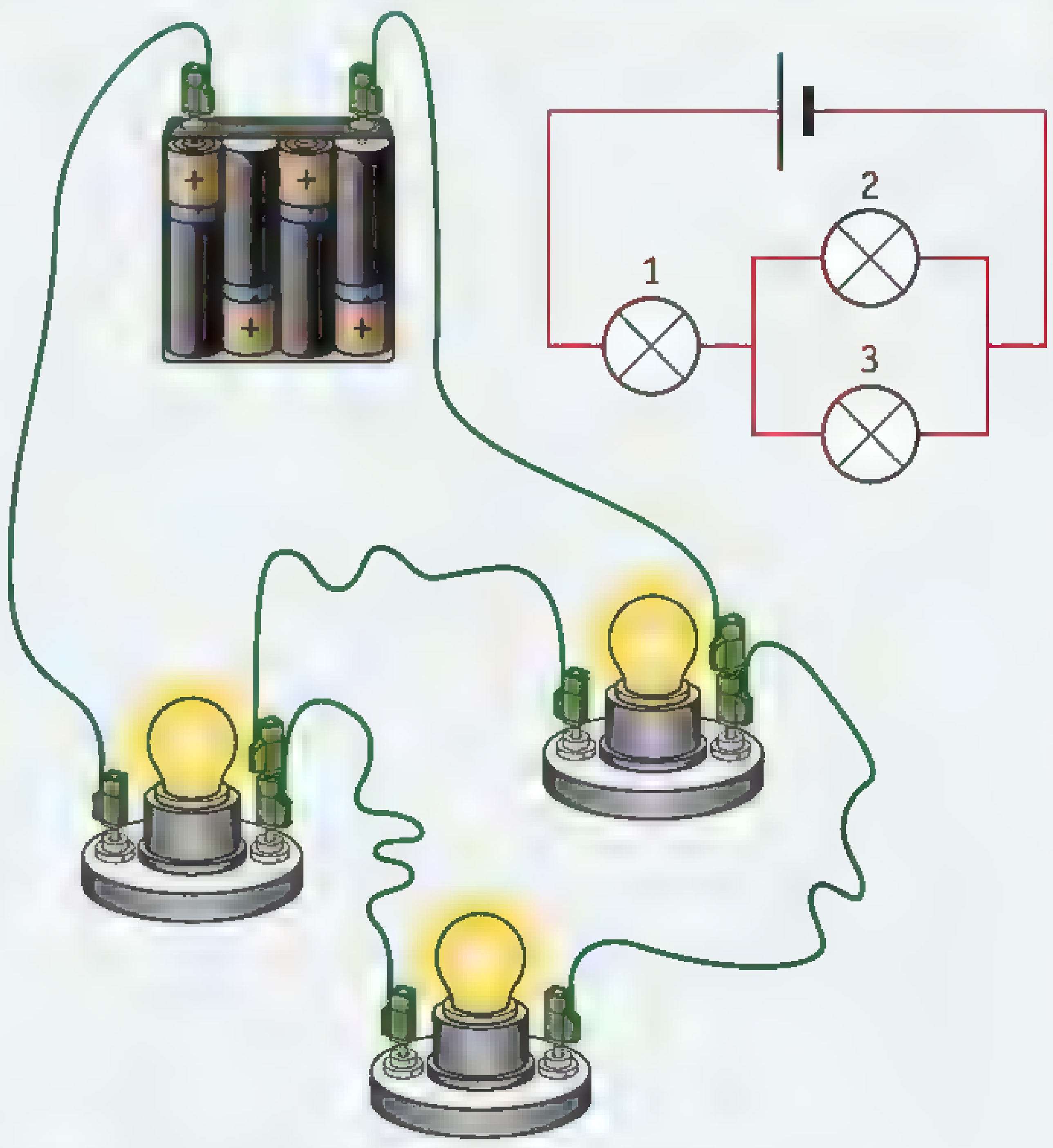


figure 7 A mixed circuit with three bulbs.

COURSE MATERIAL

1

Answer the following questions.

a How do you need to connect bulbs up if you want to switch them on and off independently?
in series / in parallel

b In what sort of circuit is the current the same at all points?
in a *series circuit / parallel circuit*

c Why are electrical devices almost always connected in parallel?

d What does the total current in a parallel circuit mean?

2

Draw the circuit diagram symbols for the following components.

a a bulb

b a switch

c a bell

d a voltmeter

IN PRACTICE

3

Figure 8 shows you a photograph of a circuit.
Draw the circuit diagram for this circuit.

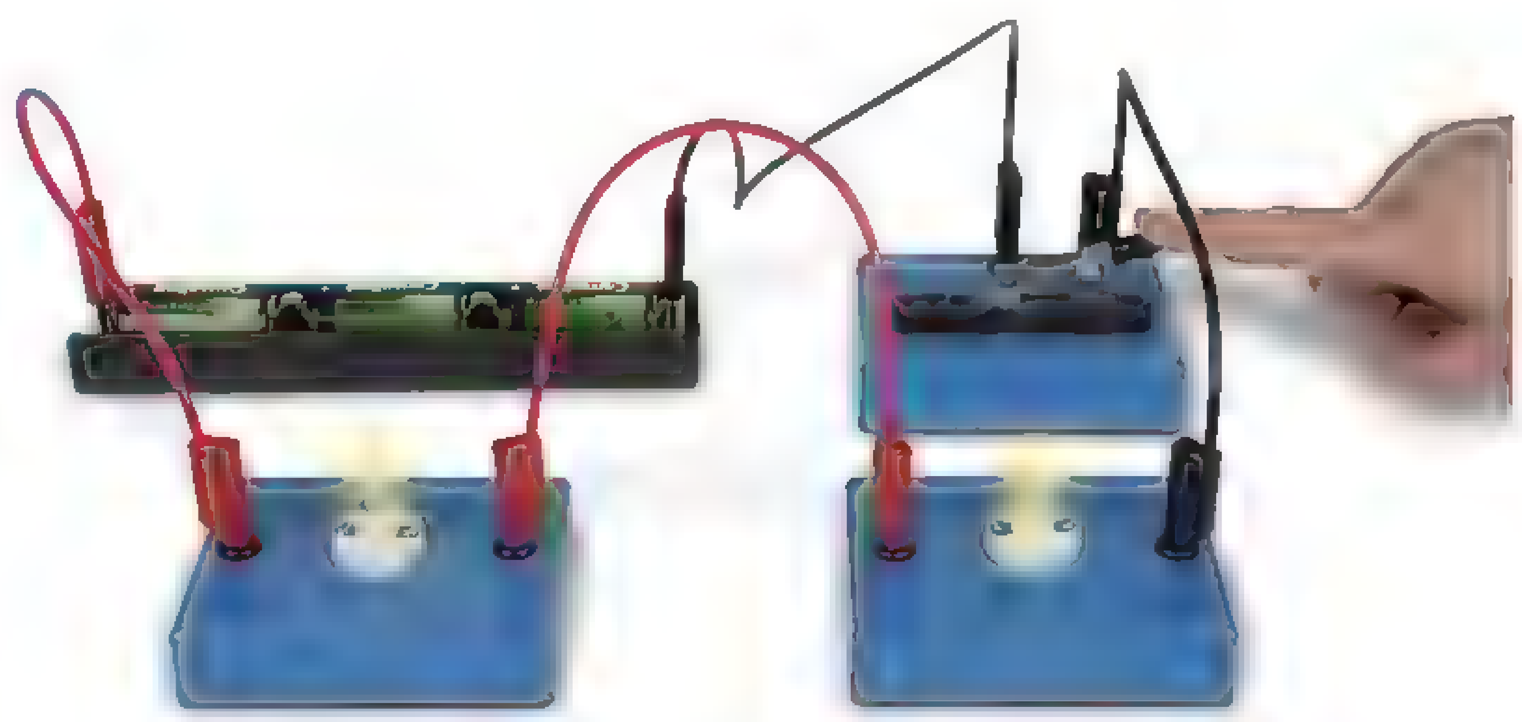


figure 8 A circuit.

4

Dylan connects up three identical bulbs in series. He then connects the bulbs up to a 9 V battery.

a Work out what the voltage across each of the bulbs is.

b Dylan sees that the bulbs are not very bright. His teacher tells him that the bulbs will be brighter if Dylan increases the source voltage to 18 V. “Use a second battery,” he says, “and it should work OK then.”
Explain how Dylan must connect up the two batteries.

c What voltage is being applied to each bulb if the source voltage is 18 V?

5

A living room is lit by two floor lamps and one desk lamp that are each connected to a socket. The bulb in one of the floor lamps dies.

a Will the other floor lamp remain lit? *yes / no*

b Will the desk lamp remain lit? *yes / no*

c So how are the wall sockets in a house connected? *in series / in parallel*

6 A car has indicators, brake lights, headlights, reversing lights and so forth.
How are these lights connected: in series or in parallel? Explain your answer.

7 Amanda has made a circuit in which two bulbs are connected up in parallel to a battery.

a Draw the circuit diagram for this arrangement. Label the bulbs 1 and 2.

b Amanda wants to add a switch that will let her turn bulb 2 on and off while bulb 1 remains lit.
Draw this switch in at the correct place on the circuit diagram.

8 Study the circuit in figure 9.
Write down which bulbs are lit:

a if switch A is open and switch B is closed.

b if switch B is open and switch A is closed.

c if both switches are closed.

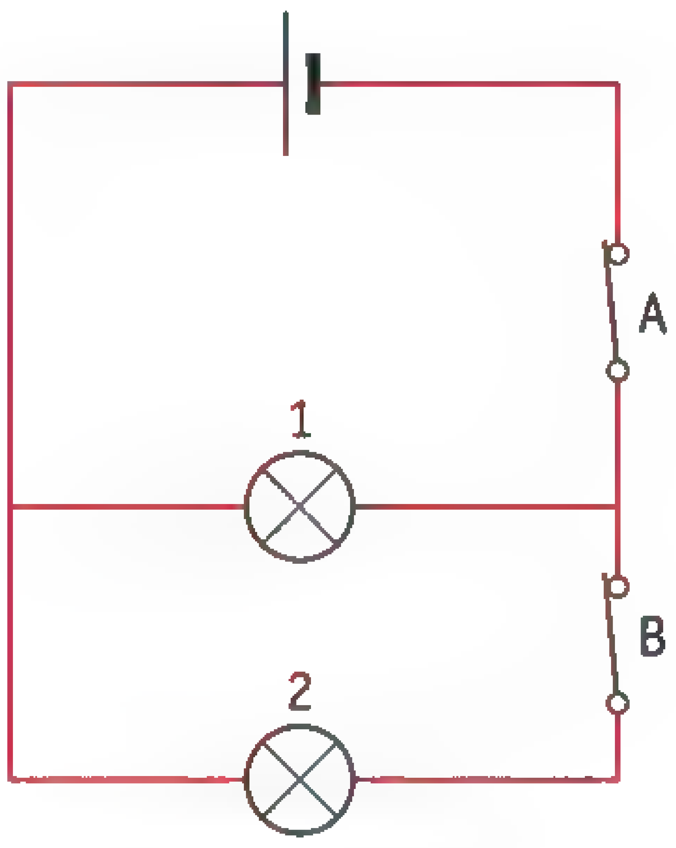


figure 9 A circuit.

★ 9 Andrew has built the circuit shown in figure 10 with four different bulbs. He has measured the current I at four points.
Calculate what the current is:

a at point A.

b at point B.

c at point C.

d at point D.

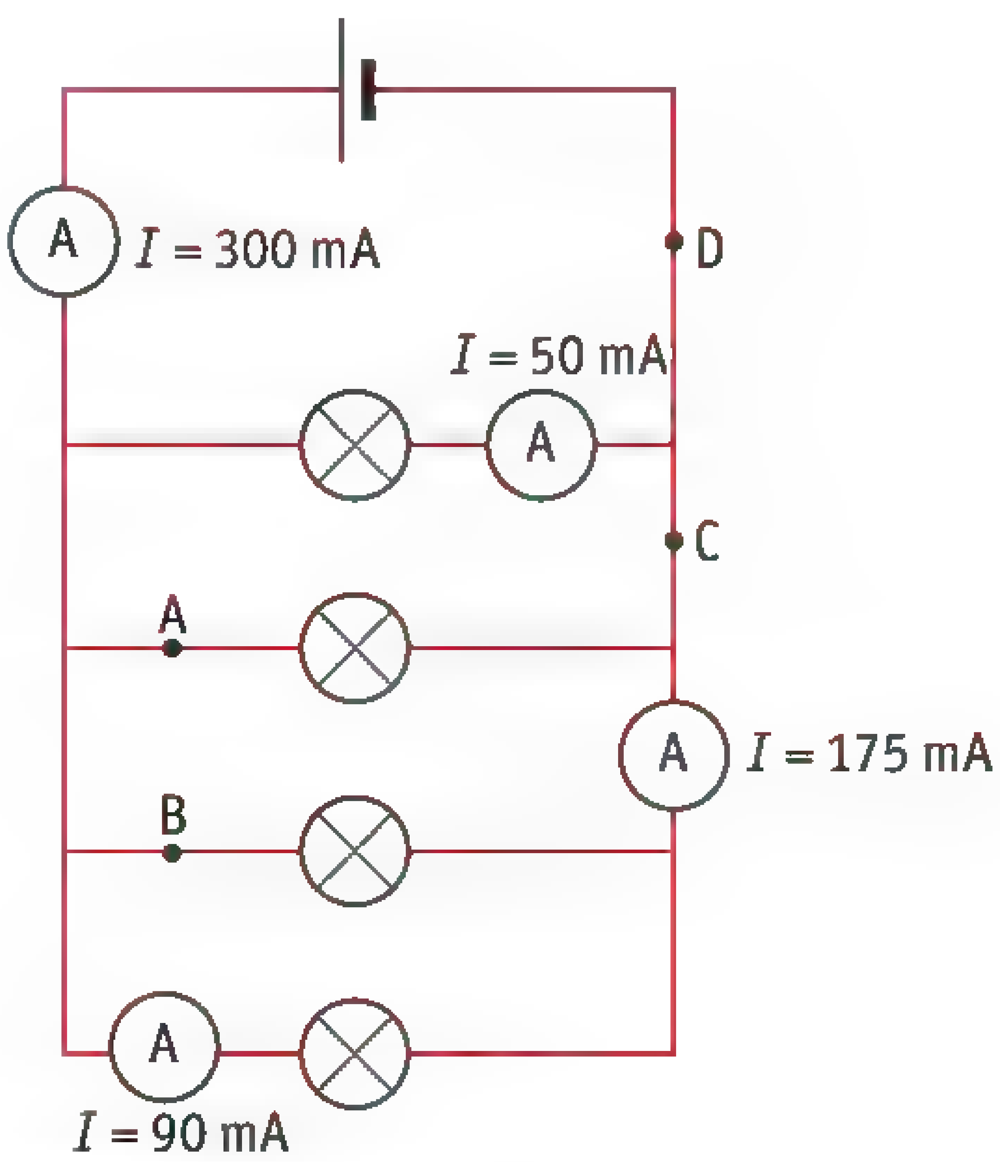


figure 10 Andrew's circuit.

Test what you know with *Test yourself.*

EXTRA MIXED CIRCUITS

10 Study the circuit in figure 11. All the bulbs are identical.

a Which bulbs go out if you unscrew bulb 1?

b Which bulbs go out if you unscrew bulb 2?

c Which bulbs go out if you unscrew bulb 3?

d Which bulbs go out if you unscrew bulb 4?

e Why does bulb 1 shine the most brightly?

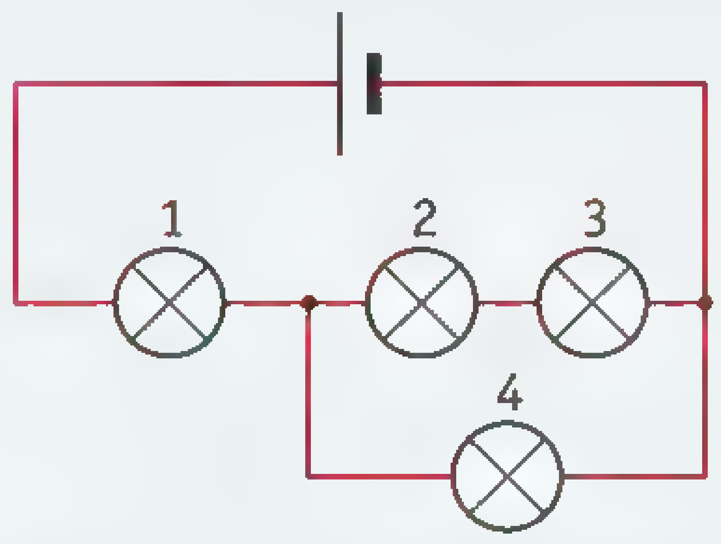


figure 11 A circuit with four bulbs.

11 Study the circuit in figure 12. All the bulbs are identical.

a Which bulbs are connected in parallel?

b Why do bulbs 1 and 2 shine more brightly than bulbs 3, 4 and 5?

c Why do all the bulbs shine equally brightly if you unscrew bulb 3?

d You have been told that the battery provides a current of 0.30 A. What is the current flowing through each of the five individual bulbs?

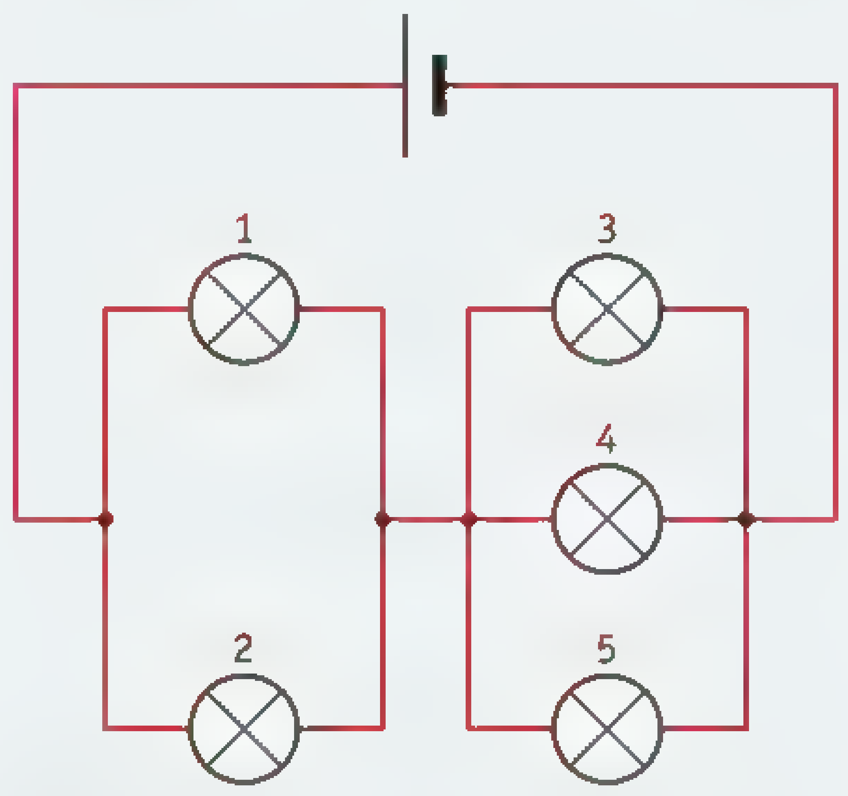


figure 12 A circuit with five identical bulbs.

4 Power and energy

LEARNING OBJECTIVES

4.4.1 You can explain what the power of a device means.
4.4.2 You can calculate the power of a device.
4.4.3 You can explain why a device with a higher power rating uses more electrical energy.
EXTRA 4.4.4 You can describe two ways of measuring how empty or full a battery is.

TAXONOMY	LEARNING OBJECTIVES AND EXERCISES					
	4.4.1	4.4.2	4.4.3	4.4.4	4.3.5*	4.2.1*
Remembering	1acd	1b, 2				
Understanding	3, 7c, 8abcde, 9ab	4a		11b		7c
Using	10b	4b, 6ab, 7b	5abc	10ab, 11a	7a	
Analysing				11c		

* You can find this learning objective in an earlier section.

A mobile phone would be much less useful if you had to keep connecting it up to the charger too often. It is therefore important that a mobile uses the available electrical energy as efficiently as possible. The more economically the device can use it, the longer it will be before the battery has to be recharged.

THE POWER OF A DEVICE

A laptop uses more electrical energy in the same time interval than a tablet does. You say that a laptop uses more power than the tablet does. The **power** tells you how much electrical energy a device uses per second. The greater the power rating, the more electrical energy the device 'gobbles up' in a single second.

The power consumption of many devices is listed on the packaging. That is the case for the bulb in figure 1, for instance. The power is generally given in watts (W), or sometimes in milliwatts (mW) or kilowatts (kW). If the power consumption is not constant, the maximum value is stated.

The power consumption of some devices varies a great deal. The power used by a mobile phone increases a lot when you are phoning or using the Internet, for example. If the phone is on standby, very little power is used at all. Some devices do have constant power ratings, such as a pocket torch or an electric clock.

figure 1 The packaging of a bulb always states the power rating.

VOLTAGE AND CURRENT

The power of a device depends on two factors:

1 the voltage that the appliance works on;
2 the current flowing through the device.

A good way of understanding how that works is to compare it to an airflow.

You can use the energy in flowing air to make a toy windmill go round. Power is then transferred from the air to the blades. This is shown schematically in figure 2. The windmill is moved by the airflow from the balloon.

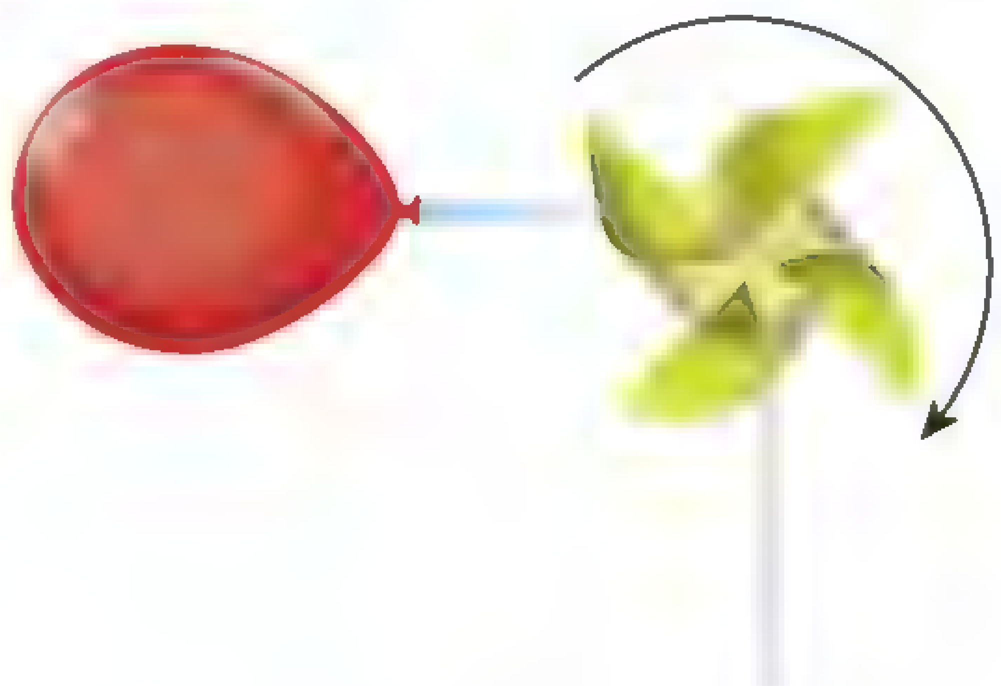


figure 2 An airflow can transfer power.

The speed the windmill turns at depends in the first place on the current (the amount of air that comes out of the inflated balloon every second). If you open the balloon's neck a little more, so that more air flows out of the balloon, the windmill's speed immediately increases.

The speed the windmill turns at also depends on the voltage (the pressure of the air in the balloon). That determines how fast the air is forced out of the balloon – and that determines how fast the windmill goes round.

A small but fully inflated balloon can make the windmill turn just as fast as a half-inflated large balloon. The small balloon's current is smaller, but the tension in it (i.e. the voltage) – and therefore the speed of the air flowing out – is higher.

CALCULATING THE POWER

The same is true for electrical devices as for the balloon in figure 2: the voltage and current together determine the transmitted power. You can see that in the formula used to calculate the power:

power = voltage × current

Or in symbols:

$$P = U \cdot I$$

where:

- P is the power in watts (W);
- U is the voltage in volts (V);
- I is the current in amps (A).

EXAMPLE EXERCISE 1

You can buy LED bulbs for decorations on a website (figure 3).
Check whether the power of the bulb in figure 3 has been calculated correctly.

given $U = 12$ V
$I = 220$ mA $= 0.22$ A

required $P = ?$

working $P = U \cdot I$
$= 12 \times 0.22$
$= 2.64$ W

This is the same as the value that is given on the website.

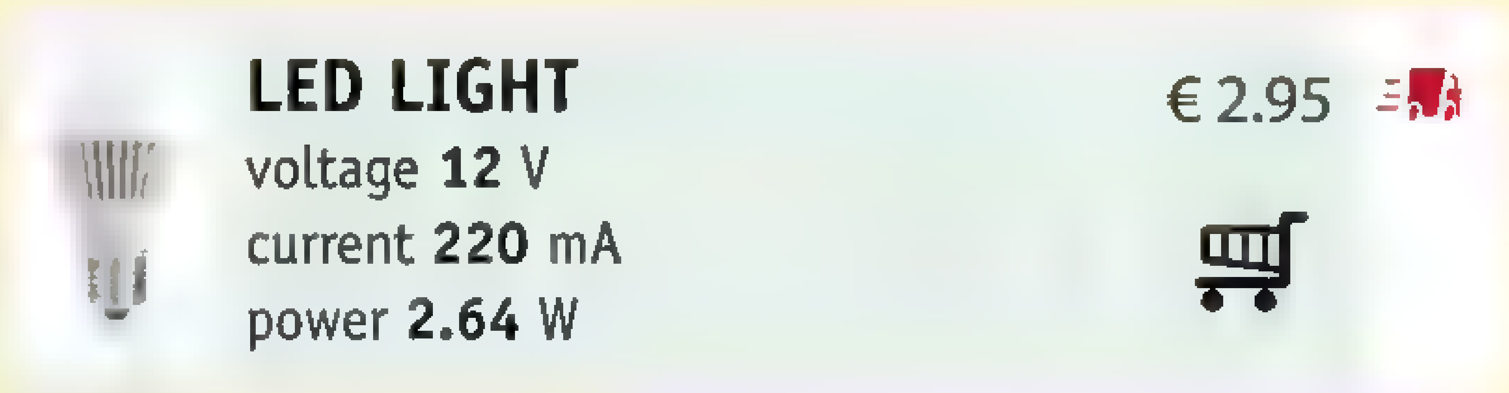


figure 3 An offer on a website.

POWER, TIME AND ENERGY CONSUMPTION

A device such as a mobile phone or a tablet can only run for a limited time on its battery. The greater the power of the device, the more quickly the battery will go flat again. All sorts of ways have therefore been thought up to help keep the power consumption of a device low.

The power of a device is the sum of the power consumed by all the individual components. The device's designers therefore choose components that use energy economically. If two screens offer roughly the same performance, the screen with the lower power rating will be preferred (figure 4).

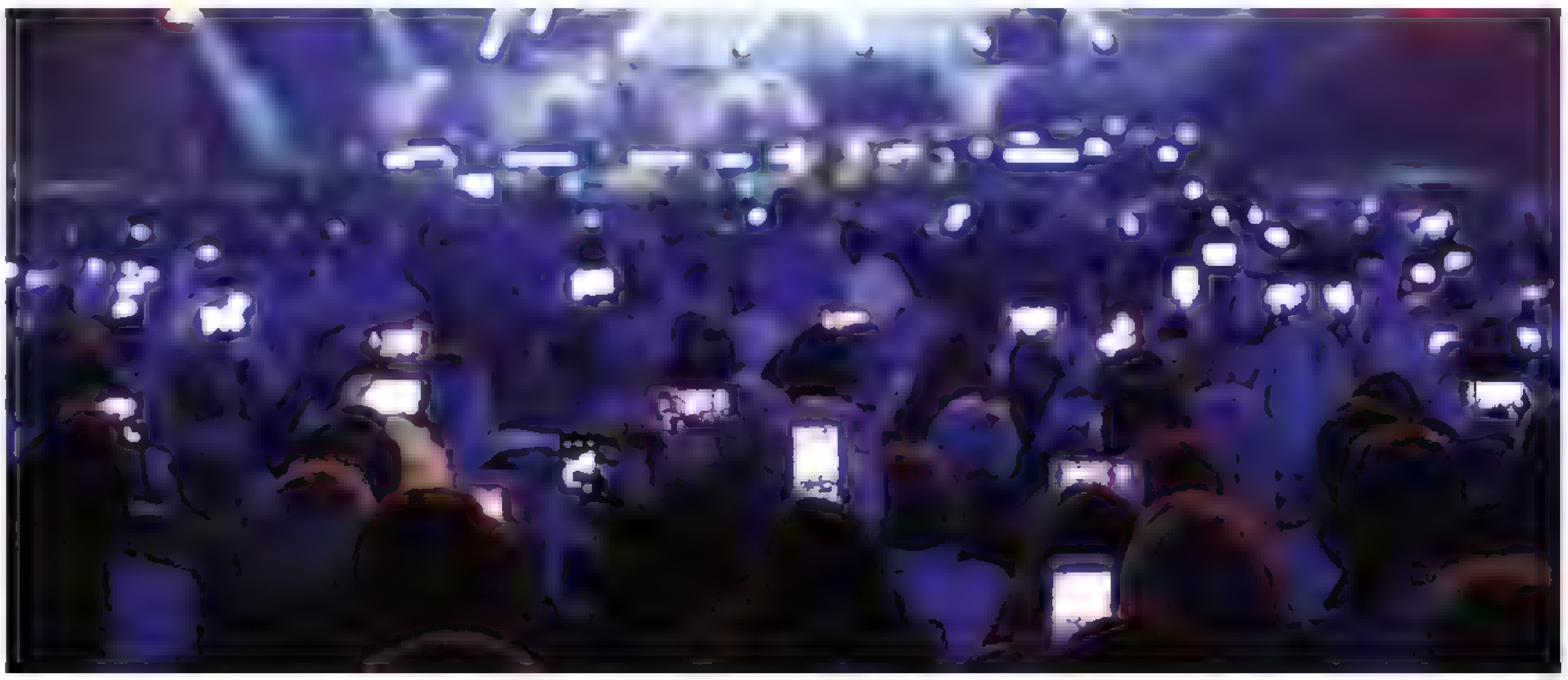


figure 4 All those screens together consume quite a lot of energy.

The software also helps keep the power down. If you do not use a mobile or a tablet for a little while, the software switches off as many components as possible. The screen, for instance, will go black after just a few seconds. This immediately reduces the overall power consumption of the device.

There is a limit to how far the power can be reduced, though, and so a great deal of research is also done on increasing the storage capacity of batteries. If a battery can store more electrical energy, a device can run on that battery for longer (at the same power).

Practice the concepts using the *Flash cards*.

EXTRA EMPTY OR FULL

If your mobile is almost out of power, it tells you that it needs to be recharged. But how does the battery tester in your phone 'know' whether the battery is empty or charged?

There are lots of simple versions of battery testers that measure the voltage that the battery is providing. The longer the battery has been in use, the more the voltage decreases, just like the tension of the balloon decreases when air flows out of it. This method is too inaccurate for the modern batteries (lithium ion batteries) in your mobile. The voltage provided by these batteries remains practically the same until the battery is almost flat.

That is why your phone usually has a special chip. During recharging, this chip measures how much charge goes into the battery, and when the phone is being used, it measures how much charge has already flowed out (figure 5). This is how the chip 'knows' exactly what percentage of the stored charge has already been discharged.

figure 5 The battery is almost recharged.

COURSE MATERIAL

1 Answer the following questions.

- **a** What factors does the power of an electrical device depend on?
- **b** What formula can you use for calculating the power of a device?
- **c** Why is the power of a mobile kept as low as possible?
- **d** How does the software in the phone help keep the power consumption low?

2 Fill in the missing data in table 1.

table 1 Electrical variables and units.

variable	symbol	unit	symbol
voltage			V
		amp, ampere	
	P		

IN PRACTICE

3 Four devices that run on electrical energy are listed below.
drill – smartwatch – television – tumble dryer
List these devices in order of their power consumption: the device that uses least first, and the one that uses most last.

4 Miranda is doing the experiment that has been drawn in figure 6.

a Write down the voltage and the current.

b Calculate the power of the motor.

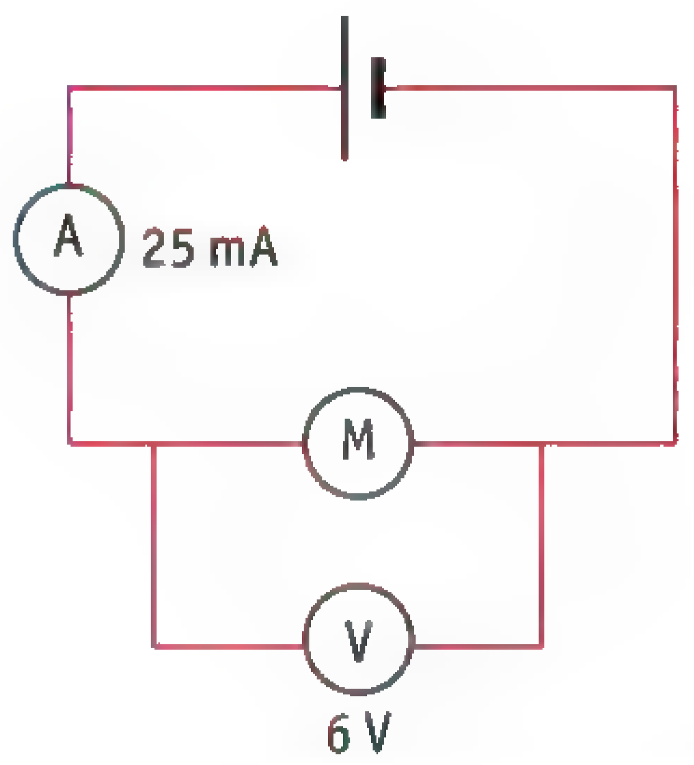


figure 6 Miranda's experiment.

5 Data for three bulbs is given in figure 7. One data item has been left out for each of the bulbs.
See the skills section on *Working with formulae*.

a Calculate the power consumed by bulb a.

b Calculate the voltage that bulb b is running at.

c Calculate the current that is flowing through bulb c.

figure 7 Three bulbs.

6 The screen of Frank's computer runs on a voltage of 12 V. When the screen is on, the current is 2.0 A.

a Calculate the power used by the screen.

b When the screen is in standby mode, the power is 0.6 W.
Calculate the current in standby mode.

7 Many places in developing countries do not have reliable electricity supplies. That is why the *Firefly Solar LED Light* was developed (figure 8). This is a desk lamp containing twelve LEDs. The lamp uses a rechargeable battery of 1.2 V. The battery is recharged using a solar panel that is supplied with it.
The current flowing through a single LED when it is lit is 18 mA. The LEDs are connected up in parallel.

a What is the total current when all twelve LEDs are on?

b Calculate the total power of the lamp when all twelve LEDs are on.

c Explain why the lamp is connected to a rechargeable battery rather than being connected directly to the solar panel.

figure 8 The *Firefly Solar LED Light*, a desk lamp that is recharged from a solar panel.

8 Tina has a phone that she uses a lot.
Does the power consumption of her phone go up or down in the following situations?

a when she is called by a friend? *up / down*

b if she turns the GPS off because she already knows where she is? *up / down*

c if she sets the screen to be brighter? *up / down*

d if she closes an app immediately after using it? *up / down*

e if she plays an online game during the break? *up / down*

9 There are various apps for mobile phones that help make sure that the battery does not have to be recharged so often. This is done above all by turning off other programs and apps that you are not using but that keep connecting to the Internet.

a Explain why the battery then needs recharging less often.

b Explain what happens to the phone's power consumption.

Test what you know with *Test yourself*.

EXTRA EMPTY OR FULL

10 Figure 9 shows how the voltage in three types of batteries decreases as they provide a constant current. A simple battery tester measures how full a battery is by measuring the voltage the battery provides.

- a Explain why this battery tester is not suitable for measuring a hybrid battery.
- b Explain how you can accurately measure how full or empty a hybrid battery is.

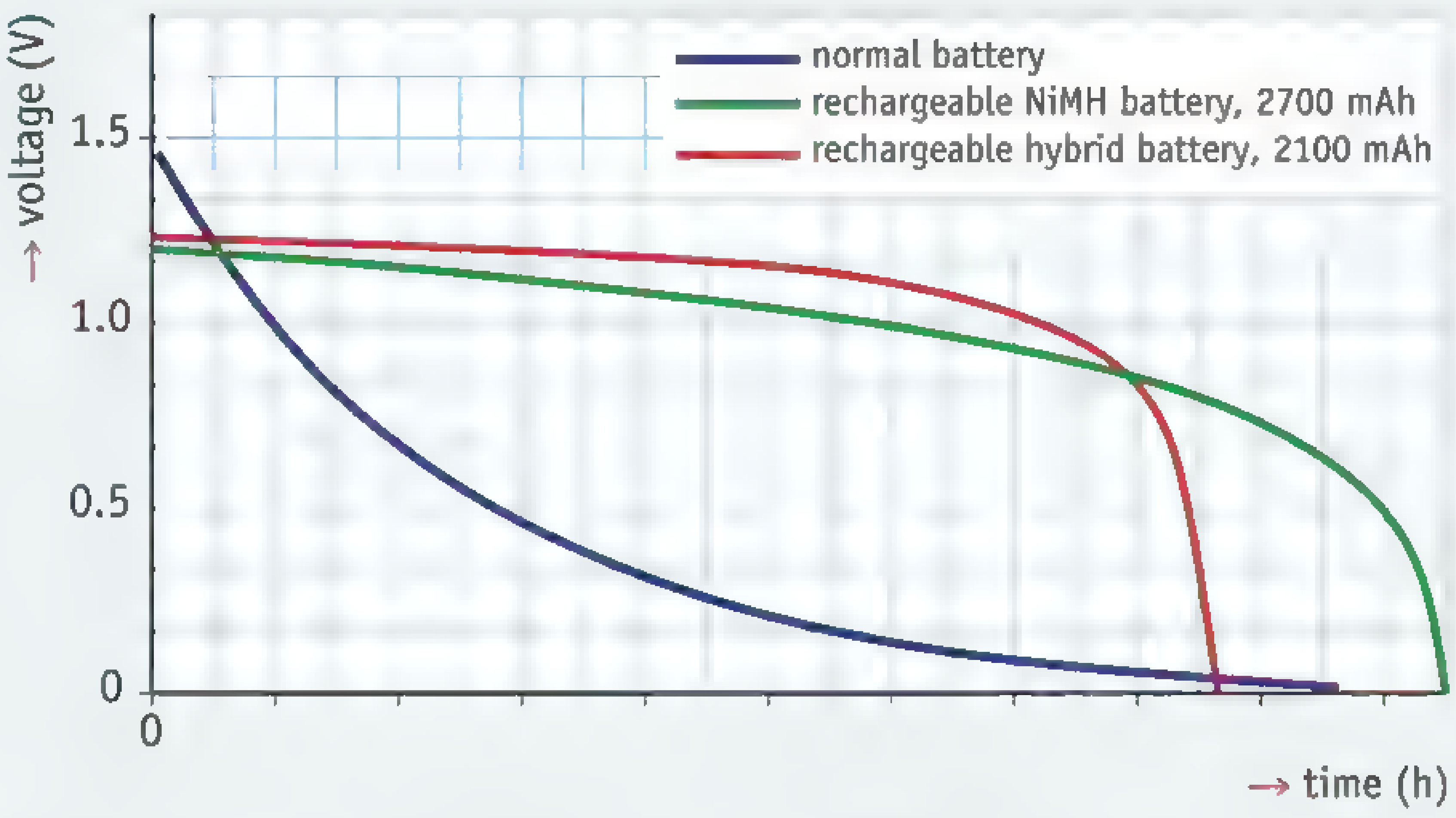


figure 9 How the voltage varies for three different batteries.

11 John is using a power bank to recharge his phone. The voltage of the power bank is 3.7 V. The charger takes a current of 0.1 A.

- a Calculate the power of the charger.
- b The phone has a chip that measures how full or empty the battery is.
  What variable does this chip measure: voltage or current?
- c The phone's battery indicates how much charge can be stored in the battery (in units of mAh). There is still a chip in the phone, though, to measure how much charge gets stored in the battery during recharging.
  Explain why this measurement is needed.

Experiments

EXPERIMENT 1 CONDUCTORS AND INSULATORS

15 minutes

Introduction
You can classify substances into conductors and insulators. Electrical currents can flow through conductors, but very little or no current can flow through insulators.

Goal
In this experiment, you will be investigating several substances to see whether they are conductors or insulators.

Requirements
- ☐ voltage source
- ☐ bulb (e.g. an LED) in a holder
- ☐ 3 wires
- ☐ copper rod
- ☐ 7 other objects

Doing the experiment and writing it up
- Make the circuit shown in figure 1.
- Adjust the voltage source to the correct voltage.
- Place ends A and B of the wires on the copper rod. You will see that the bulb lights up. So copper clearly allows an electrical current to pass. You therefore say that copper is a conductor.
- Your teacher will tell you what other objects you need for this exercise.

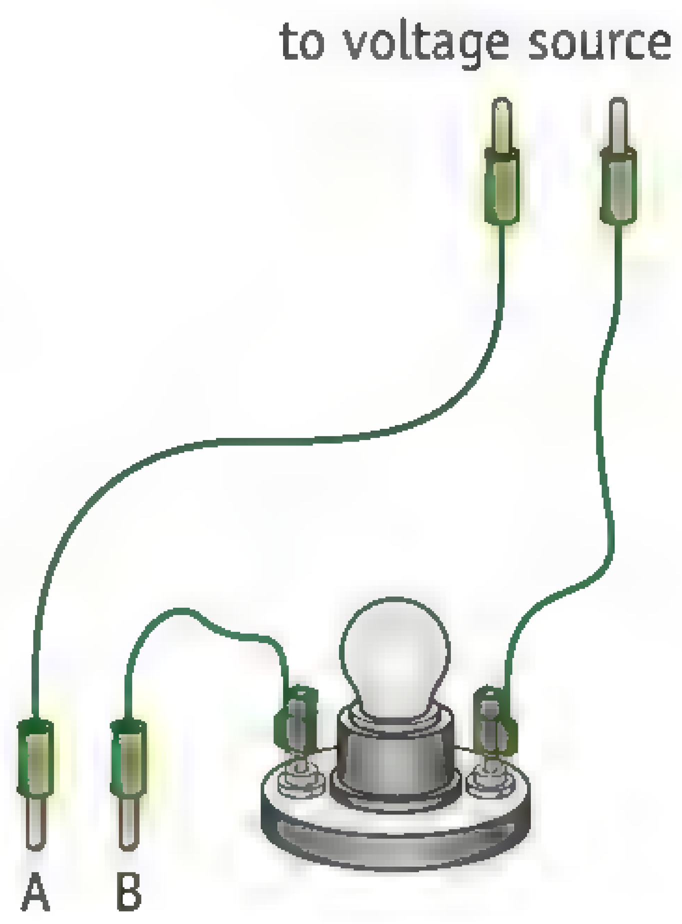


figure 1 The circuit for Experiment 1.

1 Write down in table 1:
  a the names of the various objects.
  b the substances they are made of.

- Investigate which substances are conductors and which are insulators.

2 Write down your results in the table.

table 1 Conductors and insulators.

object	made of	conductor or insulator
rod	copper	conductor

Instructions for experiments 2, 5 and 7

- To measure the current through a bulb, you connect the ammeter in series with the bulb.
- See the skills section on *Working with an ammeter.*
- Ask your teacher to check your circuit before you switch the voltage on.

EXPERIMENT 2 MEASURING CURRENTS

10 minutes

Introduction

You can use an ammeter to measure the current in a circuit. To do that, you connect the ammeter in series with the other components in the circuit.

Goal

You will practice measuring currents.

Requirements

- ☐ voltage source
- ☐ bulb (e.g. an LED) in a holder
- ☐ 4 wires
- ☐ ammeter
- ☐ switch

Doing the experiment and writing it up

- Make the circuit shown in figure 2. Use the largest measurement range.
- Get the circuit checked by your teacher!
- Adjust the voltage source to the correct voltage.
- Use the ammeter to measure the current through the bulb. Do that both to the left of the bulb and to the right.
- Switch to a smaller measurement range if possible before making your final reading of the current value.

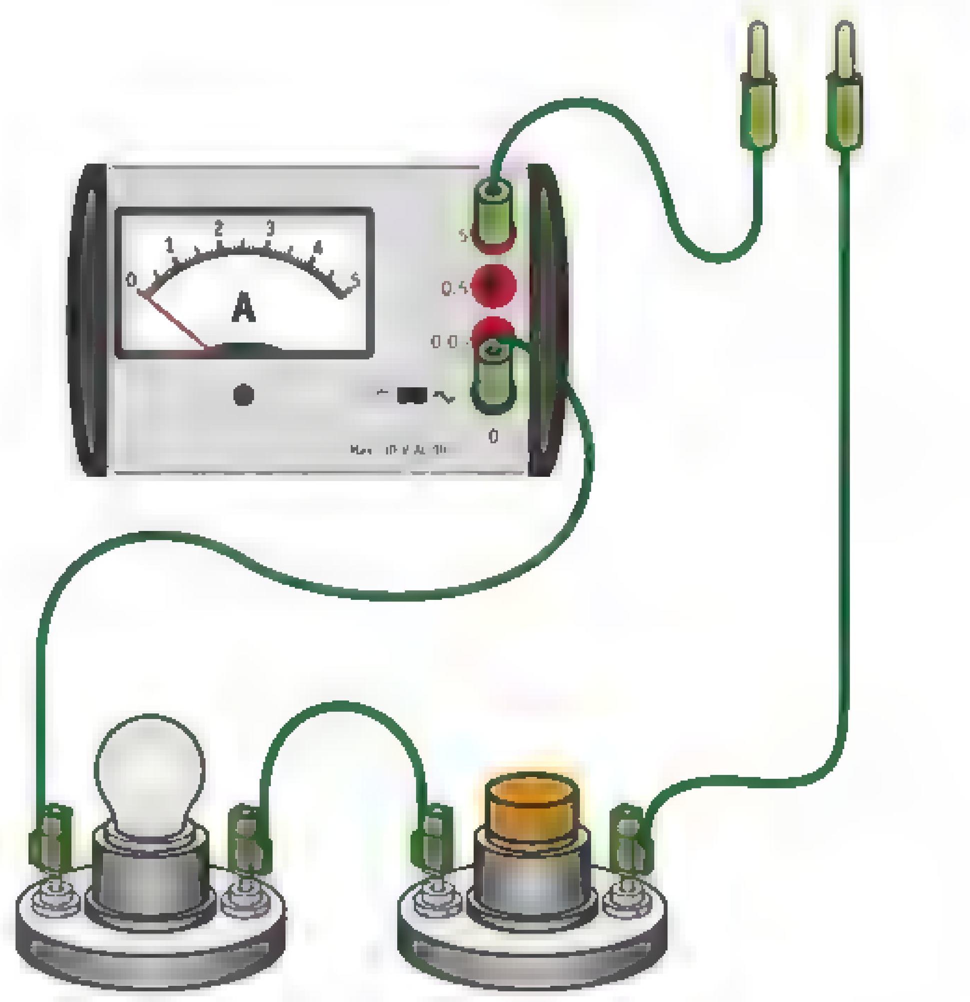


figure 2 The circuit for experiment 2.

1 What is the current through the bulb? Don't forget the units!

....

2 Does it make any difference whether you measure the current to the left or the right of the bulb?

....

....

EXPERIMENT 3 CIRCUITS WITH BULBS IN

30 minutes

Introduction

There are various ways of making circuits for bulbs, i.e. connecting the bulbs (which are conductors) to each other and to a voltage source in a way that will let you turn them on and off. Each type of circuit has its benefits and disadvantages.

Goal

You will be learning about two types of circuits in this experiment: the series circuit and the parallel circuit.

Requirements

- ☐ voltage source
- ☐ 3 bulbs in holders
- ☐ 6 wires

Doing the experiment and writing it up

Making a series circuit

First, you are going to make a series circuit with the three bulbs. That is a circuit with no splitting: the current goes from the voltage source to bulb 1 first of all, then to bulb 2, then to bulb 3 and finally back to the voltage source.

1 Draw the circuit diagram for this circuit. Label it 'A series circuit with three bulbs'.

....

See the skills section on *Building circuits*.

- Build the circuit according to the circuit diagram.
- Adjust the voltage source to the correct voltage.

2 Describe how bright the bulbs are: bright, normal or dim.

....

....

- Screw each of the bulbs loose in turn (tightening each one again before continuing).
- Remember what happens to the other bulbs each time.

3 What happens to the other bulbs?

....

....

Making a parallel circuit

You are now going to make a parallel circuit with the three bulbs. This kind of circuit will split three ways: one branch for each bulb. The current splits up into three before reaching the bulbs, so that each bulb gets one third of the current, and then comes together again after the bulbs.

4 Draw the circuit diagram for this circuit. Label it 'A parallel circuit with three bulbs'.

....

- Build the circuit according to the circuit diagram. The simplest way is to connect bulb 1 to the voltage source first. Then add the branch for bulb 2 and finally the branch for bulb 3.
- Adjust the voltage source to the correct voltage.

5 Describe how bright the bulbs are: bright, normal or dim.

....

....

- Screw each of the bulbs loose in turn (tightening each one again before continuing).

6 Write down what happens to the other bulbs each time.

....

....

- Dismantle the circuit again.

EXPERIMENT 4 EXPERIMENTING WITH A SWITCH

25 minutes

Introduction

You can use a switch to turn the current on and off. You can use it to turn just a single component on and off, or the whole circuit. That depends on where you include the switch in the circuit.

Goal

In this experiment, you investigate what effect a switch has at various points in a circuit. The question you are studying is:
How can you use a switch (a) to turn a single component of a circuit on and off, and (b) to turn various circuit components on and off at the same time?

Requirements

- ☐ voltage source
- ☐ 3 bulbs (e.g. LEDs) in holders
- ☐ 8 wires
- ☐ switch

Doing the experiment and writing it up

- Make a parallel circuit with the three bulbs.
- Adjust the voltage source to the correct voltage.
- Check that the three bulbs are working normally.

1 Make a drawing of the circuit you have constructed. Mark the wires you have used as numbers 1 to 6.

- Connect the two remaining wires to the switch.
- Replace wire 1 with the switch plus its two wires (figure 3).
- See what happens when you use the switch to turn the current on and off.

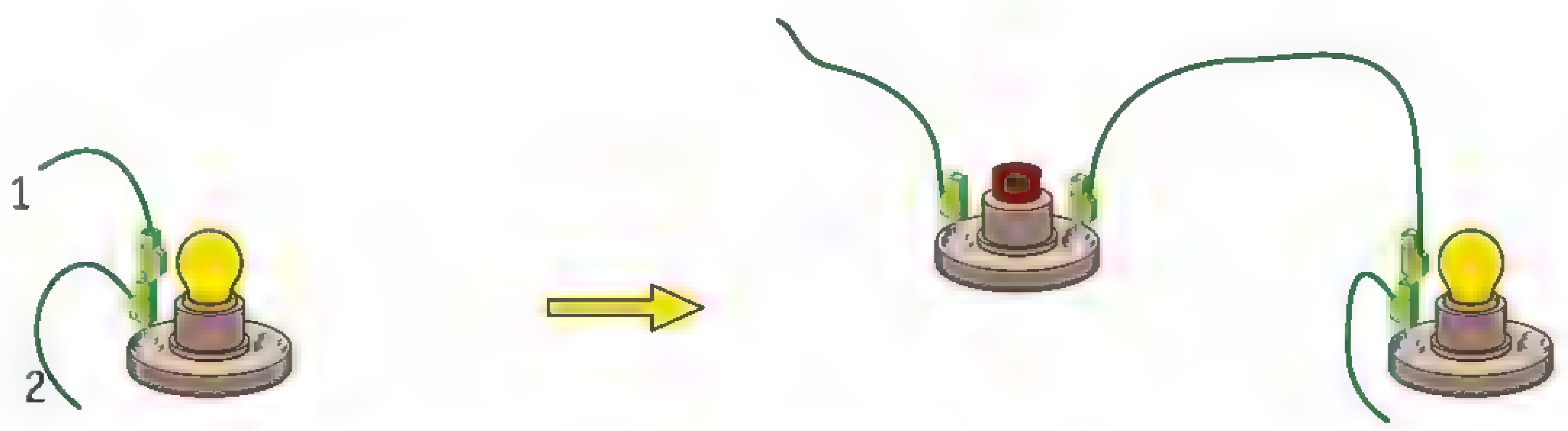


figure 3 This is how you can add a switch instead of wire 1.

2 Draw the circuit diagram for the circuit you have made.
Write down which bulbs go out when you turn the switch to OFF.

....

- Remove the switch and its two wires and connect wire 1 up again.
- Now use the switch with its two wires to replace wire 2.
- See what happens when you use the switch to turn the current on and off.

3 Draw the circuit diagram. Write down which bulbs go out when you turn the switch to OFF.

- Then do the same for wires 3 to 6.

4 Draw the circuit diagram and write down what happens.

....

....

....

5 Finally, answer the question you were studying.

EXPERIMENT 5 THE CURRENT IN A SERIES CIRCUIT

20 minutes

Introduction
You can use an ammeter to measure the current in a series circuit. You can measure the current at various points: between the voltage source and the first circuit component, between the circuit components, and after the final circuit component.

Goal
You will be investigating what rule applies for the current in a series circuit.

Requirements
- ☐ voltage source
- ☐ 2 bulbs (e.g. LEDs) in holders
- ☐ 5 wires
- ☐ ammeter
- ☐ switch

Doing the experiment and writing it up
- You are about to make a series circuit with two bulbs and an ammeter.

1 Draw the circuit diagram for this circuit.

- Get your teacher to check the circuit diagram. Then construct the circuit.
- Adjust the voltage source to the correct voltage.
- Read the value for the current. Use the ammeter's largest measurement range first. Then switch down to a smaller measurement range if possible.
- Measure the current three times: before bulb 1, between bulbs 1 and 2, and after bulb 2.

2 Write down the results. Don't forget the units.

....

....

3 What is the rule for the current in a series circuit?

....

....

....

EXPERIMENT 6 THE VOLTAGE IN A SERIES CIRCUIT

20 minutes

Introduction

You can use a voltmeter to measure the voltage in a series circuit: across each circuit component individually or across all the circuit components together.

Goal

You will be investigating what rule applies for the voltages in a series circuit.

Requirements

- ☐ voltage source
- ☐ 2 bulbs (e.g. LEDs) in holders
- ☐ 5 wires
- ☐ voltmeter

Doing the experiment and writing it up

The voltage across bulb 1

- Make the circuit shown in figure 4a.
- Adjust the voltage source to the correct voltage.
- Read the voltage. Use the voltmeter's largest measurement range first. Then switch down to a smaller measurement range if possible.

1 The voltage across bulb 1 = ... V.

The voltage across bulb 2

- Make the circuit shown in figure 4b.
- Read the voltage.

2 The voltage across bulb 2 = ... V.

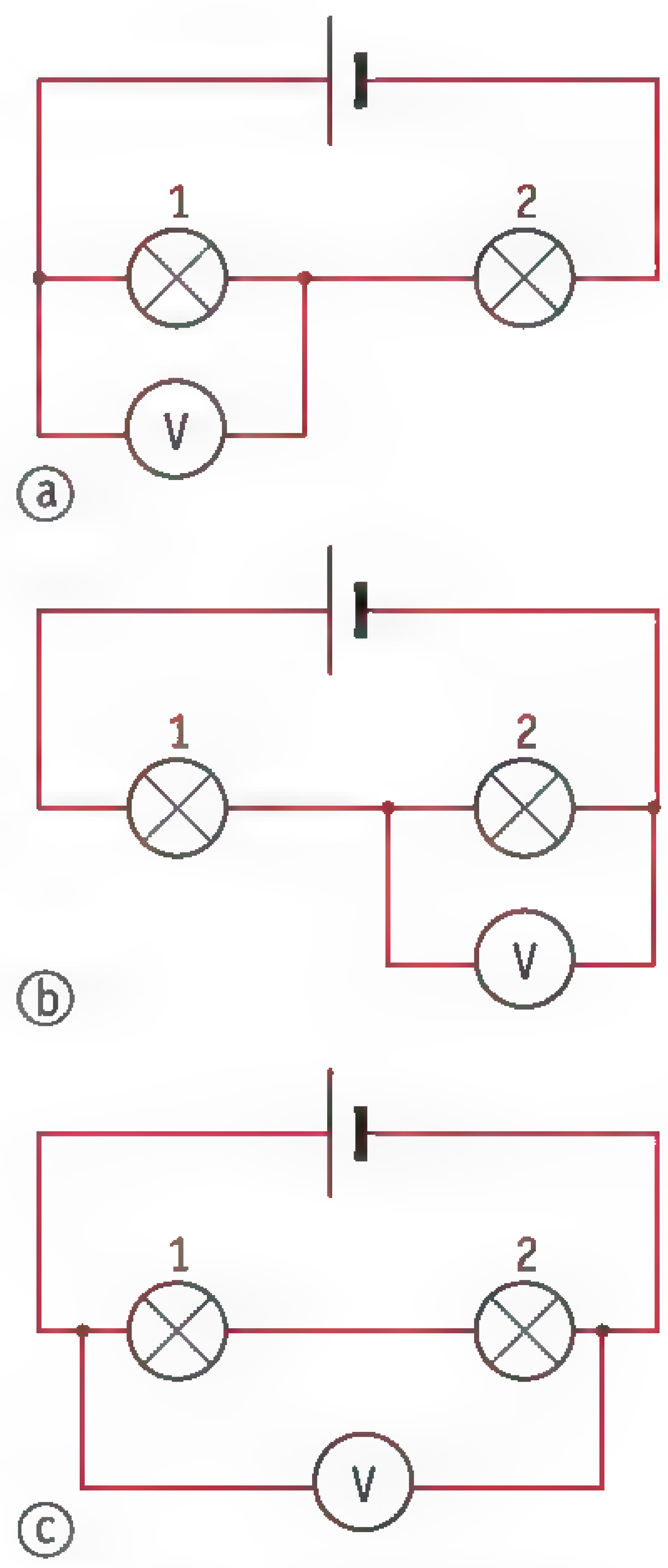


figure 4 The three circuits in Experiment 6.

The voltage across both bulbs together

- Make the circuit shown in figure 4c.
- Read the voltage.

3 The voltage across bulbs 1 and 2 together = ... V.

4 Compare the voltage of the voltage source against the voltages that you have measured.
What do you notice?

....

....

5 What is the rule for the voltages in a series circuit?

....

....

EXPERIMENT 7 THE CURRENT IN A PARALLEL CIRCUIT

20 minutes

Introduction

You can use an ammeter to measure the current in a parallel circuit. You can measure the current at various points: in the branches and in the undivided parts of the circuit.

Goal

You will be investigating what rule applies for the current in a parallel circuit.

Requirements

- ☐ voltage source
- ☐ 2 bulbs (e.g. LEDs) in holders
- ☐ 6 wires
- ☐ ammeter
- ☐ switch

Doing the experiment and writing it up

- Figure 5 shows a parallel circuit with an ammeter drawn in at four positions. In this experiment, you measure the current at these four places.

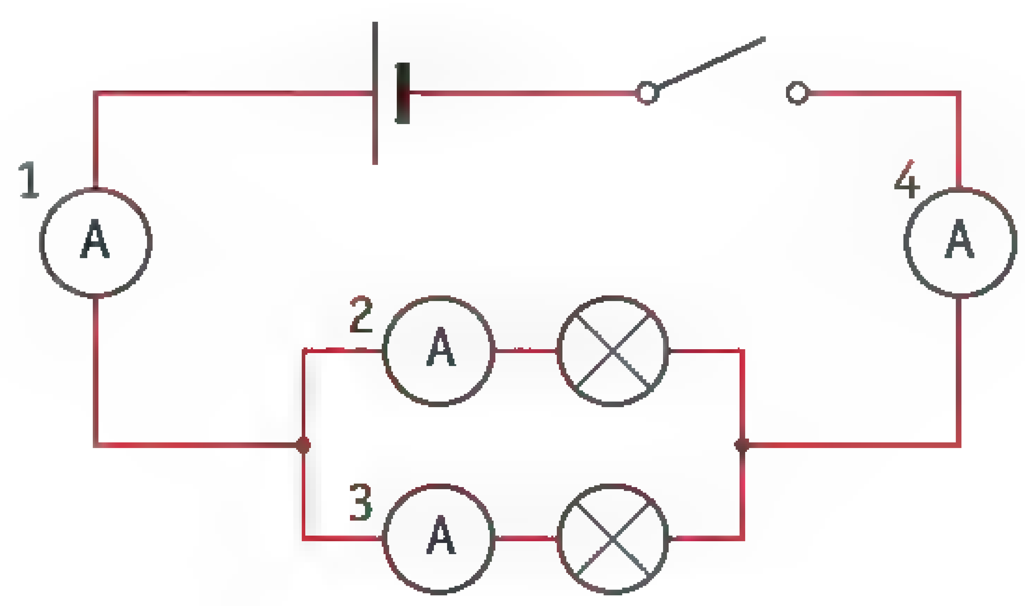


figure 5 The circuit for experiment 7.

1 What do you think: what relationship will there be between the currents you will measure at these four points?

....

....

....

- Construct the circuit shown in figure 5. Connect the ammeter at point 1.
- Adjust the voltage source to the correct voltage.
- Read the value for the current. Use the ammeter's largest measurement range first. Then switch down to a smaller measurement range if possible.

2 What is the current at point 1?

....

- Change the circuit by connecting the ammeter at point 2.
- Measure the current at point 2 as accurately as possible.

3 What is the current at point 2?

....

- Then also measure the current at points 3 and 4.

4 What is the current at points 3 and 4?

....

5 Take another look at the predictions you made for Exercise 1.
Were your predictions correct?

....

....

6 What is the rule for the currents in a parallel circuit?

....

....

....

EXPERIMENT 8 PRODUCING A DESIGN – A FOG LIGHT CIRCUIT

45 minutes

Introduction

Suppose that fog lights have to be fitted to a car. The intention is that it should only be possible to turn the fog lights on if the car's normal lights are already on. For this exercise, you are the designer who has to come up with a feasible solution.

Goal

In this experiment, you think up and test a circuit for the car lighting, including the fog lights. Your prototype must meet the following design requirements:

Design requirements

- The circuit consists of five bulbs and two switches.
- Bulbs 1 and 2 represent the headlights.
- Bulbs 3 and 4 represent the rear lights.
- Bulb 5 represents the rear fog light.
- The headlights and the rear lights can be turned on and off using switch 1.
- The rear fog light can be turned on with switch 2, but only if the headlights and the rear lights are on.

Requirements

For this experiment, you have to think up for yourself what equipment you will need.

Doing the experiment and writing it up

- Think how you can carry out the exercise. What circuit are you going to build, what equipment will you need for it and how are you going to test whether the circuit is working properly?

1 Make a work plan for this exercise.

- The work plans will be discussed with the rest of the class in the next lesson. If necessary, you can make improvements to your own work plan after that.
- Build the circuit and test it out.

2 Make a test report that includes:
 a a circuit that meets all the design requirements.
 b the tests you carried out and the results you got from them.
 c any changes that you made to your circuit.

A solar energy competition

On the final race day, the Nuon Solar Team (Delft University) extended their lead over their key competitors – Michigan (USA), Tokai (Japan) and Punch Powertrain (Belgium). Red Shift (University of Twente) had to sit out a time penalty of half an hour and dropped back in the final positions. The Nuon Solar Team comfortably won the fourteenth Bridgestone World Solar Challenge, the official world championship for solar-powered cars in Australia. The team and their solar-powered car Nuna9 took four days and a little over six hours to complete the 3000-km race. It was the seventh time that the Nuon Solar Team has won the solar racing world championship.

The *World Solar Challenge*

Every two years, a few dozen teams gather for the *World Solar Challenge*, a race for solar-powered vehicles through the Australian outback. The route goes from Darwin in the north to Adelaide in the south, covering a distance of more than 3000 km. The race is particularly tough for the drivers: For five or six days, they are enclosed in a tiny little cab in which the temperature can get up to 50 °C or more.

The race started once again on 8 October 2017. Just as in 2013 and 2015, there were three Dutch teams: the Nuon Solar Team from Delft University (figure 1), Solar Team Twente from the University of Twente and Solar Team Eindhoven from the Technical University of Eindhoven. The car from Eindhoven was the winner in the Cruiser class with their Stella Vie. This class, which was introduced in 2013, is for cars that are somewhat more practical to use, with two to four occupants. The team from Eindhoven is as yet unbeaten in this class: they have won it every time so far.

Driving on sunlight

The vehicles taking part in the *World Solar Challenge* run entirely on solar energy. The Nuon Solar Team's car Nuna9 has solar cells made of gallium arsenide, with an overall surface area of just 2.64 m^2.

figure 1 Lisanne de Rooij, driver of the Nuna9 for the Nuon Solar Team.

figure 2 To catch as much sunlight as possible, the solar panels are set at an angle.

When the sun is shining brightly, that is enough for it to reach a speed of 110 km/h. The vehicles are not allowed to go faster than that: like all traffic, they have to observe the Australian speed limits.

In sunny weather, the solar cells generally produce more electrical energy than is needed at that time. The energy is not lost, though: the excess is stored temporarily in batteries. That is very useful if there is a shortage of energy later in the day, for example because the sun is suddenly obscured by clouds. The energy that has been saved up in the batteries can then be used to power the solar vehicle.

Recharging and discharging

The batteries also play a key role at the start. Getting up to speed quickly requires a lot of power – a lot of energy over a relatively short time. Owners of cars with internal combustion engines know all about that: taking off quickly guzzles gas. The same is true for a solar-powered car (though it is electrical energy rather than petrol that is being guzzled). Because solar cells are only able to supply a limited amount of power, the batteries have to help a lot when getting the car moving.

"Australia is a sunny country, but, the sun's not going to be shining all the time."

The batteries are therefore charged up in the morning before the start, using the solar cells. The competing teams also try to get their batteries fully recharged during the stops. They set the solar panels up at angles designed to catch as much sunlight as possible (figure 2). The more electrical energy they can store in their batteries, the better their chances in the race.

Continually recharging and discharging the batteries can be a risky business, though. A couple of years ago, one of the competing teams had a fire in the batteries. A lot of the solar-powered cars therefore have a special battery management system that is constantly monitoring the battery charge. The system makes sure that the batteries cannot become overcharged, or indeed discharged too far, as they could catch fire in either situation.

Strategic driving

A well-designed solar car is no guarantee that you will win the race. It also requires intelligent driving. When the weather is not very sunny, you cannot drive at full speed all the time. The batteries would then be exhausted way before the finish. Going too slowly is not a good idea either, of course. You want to make the best possible use of the energy accumulated in the batteries.

figure 3 The Nuon Solar Team became world champions for the seventh time.

The successful teams therefore adopt a carefully thought-out strategy that the people in the team car following the solar vehicle are constantly working on. The electronics in the solar-powered car pass data on to the team members about the energy production of the solar cells and the charge levels of the batteries. They also monitor the weather forecasts closely. They use all this information to work out the optimum speed for the solar car. This information is then given to the driver.

The third and fourth race days were decisive, when the weather in the Australian outback changed, with dark clouds, high winds and even rain. And it was precisely under those conditions that the Nuon Solar Team extended their lead to two hours (figure 3).

When there was a lot of cloud cover, the driver would take their foot off the pedal. Jasper Hemmes, an aerodynamicist, explained. "Because Nuna is so light and streamlined, we were able to keep going at a good speed without using much energy even in high winds. Thanks to our aerodynamic design, the wind almost sucked us along, as it were." The team's strategist Stijn Burger added, "On top of that, thanks to good information from our meteo team, we were able to make the most of the gaps in the cloud cover and maximize the sunlight we could catch."

Finish

The team from Twente finally finished fifth. Two first places and a fifth is a fantastic performance, of course, but the competitors aren't standing still. There are undoubtedly enough enthusiastic students in Delft, Twente and Eindhoven to make sure that the next *World Solar Challenge* will also be an exciting high-tech event.

PROBLEMS FOR UMICORE

The Umicore Solar Team from Belgium had a major setback in the *World Solar Challenge* a couple of years ago. The team was in a very creditable fourth place when fire broke out in one of the batteries about 200 km from the finish. The driver and several team members were taken to hospital for a check-up because they had inhaled smoke, but they were soon allowed to leave again. After emergency repairs, the vehicle was able to continue on the spare batteries.

EXERCISES

1 During the stops, the solar panels are often placed at an angle.

a In which direction should the driver tilt the solar panels?

b Why does that position mean that the batteries will be recharged more quickly?

2 Explain why the batteries of a solar vehicle are used to help in the following situations:

a when the sun disappears behind clouds.

b when the solar car drives up a hill.

c when the driver is going to overtake another vehicle.

3 When there was a lot of cloud cover, the driver would take their foot off the pedal.

a Explain exactly what the driver meant by 'taking their foot off the pedal'.

b Explain why this had to be done.

4 Suppose that there are three switches in the electrical system of a solar-powered car:

- switch 1: between the solar panels and the batteries;
- switch 2: between the solar panels and the motor;
- switch 3: between the batteries and the motor.

Which switches are open (OFF) and which are closed (ON):

a when the batteries are being charged as fully as possible before a race?

b when the car is driving quickly uphill during the race?

c when the car is driving at 110 km/h on a flat road in sunny weather?

Course material overview

4.1 MAKING AN ELECTRICAL CIRCUIT

REMEMBER

- A closed electrical circuit is a circuit without interruptions that electrical currents can flow through.
- Substances that electrical currents can flow through easily are called conductors. All metals are conductors. Carbon is a conductor too, even though it is not a metal.
- Substances that do not allow electrical currents to pass through (or only very poorly) are called insulators. Examples are rubber, glass and most plastics.
- You can use an ammeter to measure the current through a bulb, for instance. It does not matter whether you measure before or after the bulb in the circuit: the current is the same in both places.

CONCEPTS

conductor
A substance that electrical currents can flow through easily.

insulator
A substance that does not allow electrical currents to pass (or only very poorly).

charge
The quantity of electricity. An electrical current consists of charge that moves through components of a circuit.

switch
A component of a circuit that can be used to open or close the circuit.

circuit
A set of conducting components of wires, bulbs and so forth through which current can flow.

ammeter
An instrument you can use to measure how much current is flowing through a circuit.

current
The amount of charge passing per second.

4.2 VOLTAGE SOURCES

REMEMBER

- You can check a voltage source's stated voltage with a voltmeter. To do that, you need to connect the meter across the positive and negative terminals of the battery. You measure the voltage in volts (V).
- You can compare electrical voltage to the tension of an inflated balloon. The higher the tension (i.e. the voltage), the greater the 'pressure' forcing the charge to move through a circuit.
- There is an electrical component that behaves just like a balloon: a capacitor. You can store charge in the capacitor. The capacitor does not provide a constant voltage.
- In a circuit you often use a voltage source (e.g. a battery) that gives a constant voltage.
- You can only use normal batteries once. You can recharge rechargeable batteries by passing current through them in the opposite direction.
- If you connect batteries in series properly ('head to tail'– the plus to the minus), you can add their voltages together.

CONCEPTS

rechargeable battery
A battery you can recharge.

mains voltage
The voltage of electrical sockets. The mains voltage in the Netherlands is 230 V.

voltage
A type of 'electrical pressure': the higher the voltage, the greater the 'pressure' that forces the charge to move through a circuit.

voltage source
The component of a circuit that provides the voltage, for example a battery.

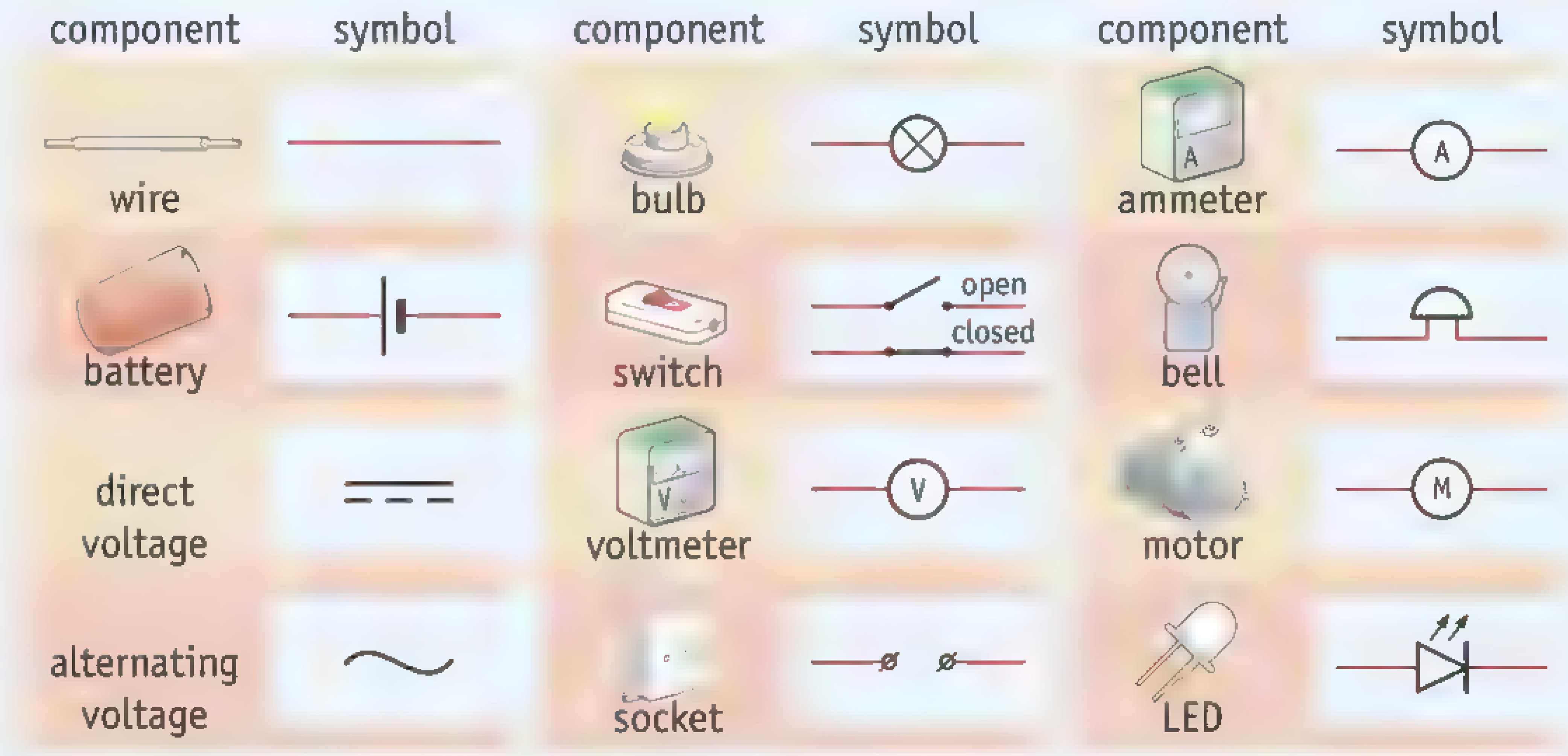
voltmeter
An instrument you can use for measuring voltages.

transformer
A device that converts mains voltage into other voltages (usually lower).

4.3 CIRCUITS

REMEMBER

- In a circuit diagram, electrical components are shown using symbols.



- The current in a series circuit is equally strong throughout.
- In bulbs in a series circuit, the voltage that the battery provides will be split across the bulbs.
- In bulbs in a parallel circuit, the total current (the current that the battery provides) is the sum of the currents through the branches.
- In bulbs in a parallel circuit, every bulb will get the same voltage: the source voltage.
- In a parallel circuit, you can turn each bulb on or off individually. If one of the bulbs burns out, the others will keep working.

CONCEPTS

source voltage
The voltage of the voltage source, for example a battery.

parallel circuit
A circuit with multiple closed pathways.

circuit diagrams
A clear drawing of a circuit, shown using symbols.

series circuit
A circuit that consists of one closed pathway without branches.

total current
The current in the unbranched part of a parallel circuit.

4.4 POWER AND ENERGY

REMEMBER

- The power tells you how much electrical energy a device uses in one second. Devices with high power consumption use more energy in one second than devices with low power consumption. The unit of power is the watt (W).
- You calculate the power of an electrical device with the formula $P = U \cdot I$.
- The power consumption of a device depends on the power rating of the device and the times it is powered on for.

CONCEPTS

power
The amount of electrical energy that the device uses per second.

Go to the *Flash cards* and the *Diagnostic test.*

Skills

DOING RESEARCH

Physics and chemistry are subjects that teach you how to do research. You work with practical equipment, make measurements, draw graphs and do calculations. This part of the book is about the skills that you need in order to do this.

1 Carrying out research

Physics and chemistry are subjects that teach you how to carry out research yourself. When you are doing research, you set about it step by step.

Step 1: **Think of a study question**

The question you are investigating is usually already stated in the book – in which case this step won't take long. Sometimes the book lets you think up a study question of your own, though. Don't be content with it too quickly. And you must have some idea of how you could answer your question.

Step 2: **Make a working plan**

In your working plan, you should write down:

- what materials and equipment you will need;
- what experimental setup you are going to construct (make a drawing);
- what variables you are going to measure;
- which formulae you are going to use (if applicable).

Figure 1 gives an example of a working plan.

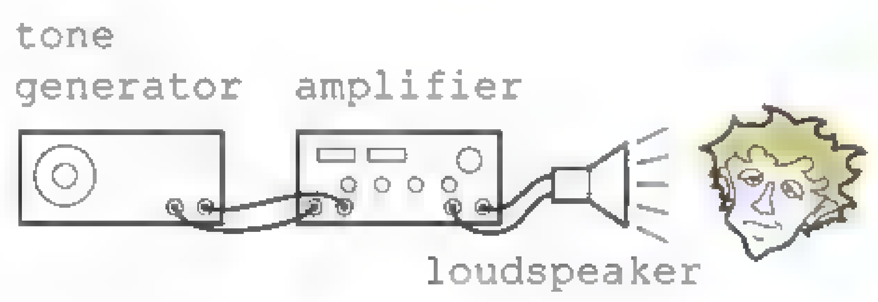
```
Working plan by: Eileen and Jamila

Study question: What is the highest tone
we are able to hear?

1   Materials and equipment

  * Tone generator
  * Amplifier
  * High-frequency loudspeaker

2   Setup
```




```
3   Measurements

Jamila uses the tone generator to produce
increasingly high-pitched sounds. Eileen
says "stop" when she can no longer hear
the sound. Jamila then looks at the tone
generator to see how high the frequency was.
We do this a number of times to see if we
consistently get the same value. Then we
do the test again, but this time with Jamila
listening and Eileen turning the knobs
on the tone generator.
```

figure 1 A working plan may look something like this.

Step 3: **Doing the experiment and writing it up**

You are now going to make the measurements and do the calculations with them. See also Skills 5 to 11.

Step 4: **Drawing conclusions**

If everything has gone as intended, you are now able to draw your conclusions. Try to give an answer to your study question. You should also think about what you could have done better in your research.

Step 5: **Writing a report**

Finally, you make a report of your research. See the skills section on 'Writing a report'.

2 Working with variables and units

Experiments and study assignments often need you to make measurements. You use a measuring instrument to find a numerical value for a property, such as a length or a temperature.

Variables

A variable is a property that you can measure with a measuring instrument. Examples of variables are length, mass and temperature. You can measure these variables with a ruler (for the length – see figure 2), scales (for the mass) or a thermometer (for the temperature).

figure 2 The variable 'height' is measured in the unit 'metres'.

Units

Before you can measure a variable, a scale of sizes has to be agreed. This scaling is known as a unit. You measure lengths in metres, mass in kilograms and your body temperature in degrees Celsius.

There is an internationally recognised SI unit for every variable, such as the metre for length, the second for time and the ampere for the strength of current. Other units are also used in daily life. People do that because they find these units handier, or simply because it is what they're used to.

Writing down measurement results

- Before making the measurements, determine what units your measuring instrument gives the results in. That is often immediately clear, but sometimes you do have to look carefully first.
- Always write a measurement result down straight after taking the measurement.
- If you are you only making a single measurement, write the measurement result down in this form:
  [variable] = [number] [unit].
  For example, mass = 237 grams or m = 237 g.
- If you are making a series of measurements, you should then record your measurement results in a table. Above each column of numbers, you should write:
  - what variable you have measured;
  - which units you have used (in brackets).

Table 1 gives a summary of the variables and units that you will come across in this book. The third and fourth columns give the SI units. Other widely used units are listed in the last two columns.

Sometimes you have to convert a value from one set of units to another (for instance from km/h to m/s). See Skills 4 for this.

table 1 Variables and units.

variable	abbreviation	SI unit	abbreviation	other units	abbreviation
air pressure, gas pressure	*p*	pascal	Pa	bar	-
current	*I*	ampere	A	-	-
density	*ρ*	kilograms per cubic metre	kg/m^3	grams per cubic centimetre	g/cm^3
frequence	*f*	hertz	Hz	-	-
length, distance	*l*	metre	m	-	-
mass	*m*	kilogram	kg	-	-
power	*P*	watt	W	-	-
speed	*v*	metres per second	m/s	kilometres per hour	km/h
temperature	*T*	kelvin	K	degrees Celsius	°C
time	*t*	second	s	minute, hour	min, h
voltage	*U*	volt	V	-	-
volume	*V*	cubic metre	m^3	litre	L

3 Working with prefixes

A unit may sometimes be awkwardly large or indeed awkwardly small. A method has therefore been developed for making units that are the 'right size'.

The prefixes in table 2 can in principle be used for any unit. You can for example make derived units that are 10, 100 or 1000 times larger or smaller than the original unit. This lets you adjust the size of the unit to suit the situation: kilograms for the mass of your body, but milligrams for the amounts of active ingredient in a tablet.

In practice, some combinations are widely used and others very rarely or never. The decibel (dB) is a popular unit, for example, but you will never come across a decivolt (dV) or deciwatt (dW).

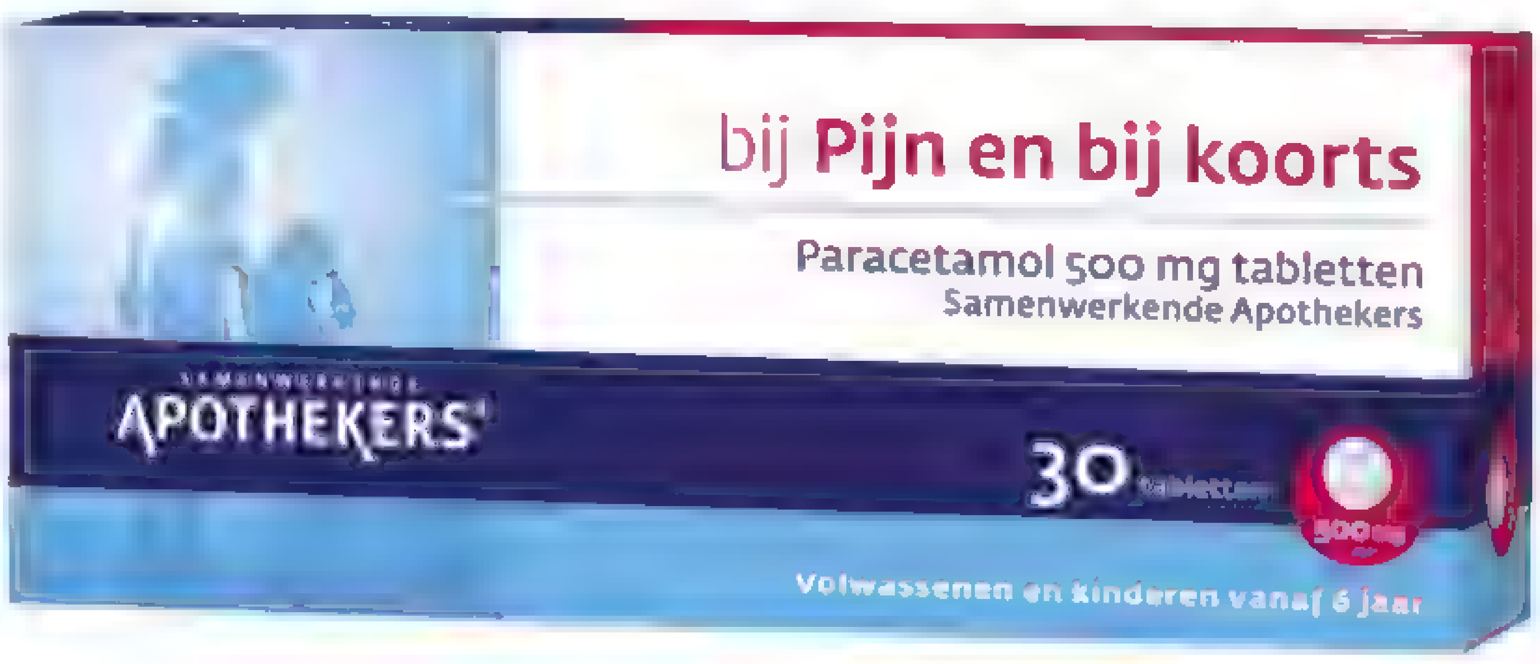


figure 3 A painkiller with 500 mg of the active ingredient per tablet.

Choosing a unit

- When doing your experiments, you should look to see what units are stated on the measuring instrument. It is generally simplest to use those units.
- Choose a smaller unit if you would otherwise end up using very small numbers (< 0.1). Write down the result of a volume measurement as 25 mL, for example, rather than 0.025 L.
- Use a larger unit if you would otherwise end up with very large numbers (> 1000). Write down the result of a calculation as 340 km, for example, rather than 340,000 m.

Sometimes you have to convert a value from one set of units to another (for instance from mA to A). See Skills 4 for this.

table 2 Prefixes and their meanings.

prefix	abbreviation	meaning	example
kilo	k	1000	1 kg = 1000 g
hecto	h	100	1 hPa = 100 Pa
deca	da	10	1 dam = 10 m
deci	d	1/10 or 0.1	1 dL = 0.1 L
centi	c	1/100 or 0.01	1 cm = 0.01 m
milli	m	1/1000 or 0.001	1 mA = 0.001 A

4 Converting units

You often have to convert from one set of units to another. You might for instance do this if you have calculated the speed in m/s but someone asks you what that is in km/h.

When you need to convert units, you do it as follows:

Step 1: **Write down an equation with one unit on the left and the other on the right.**

Step 2: **Determine which number you need to multiply or divide.**

Step 3: **Do the appropriate multiplication or division and write down the result.**

EXAMPLE EXERCISE 1
A measuring cylinder contains 0.125 L water. How many millilitres is that?

Step 1: Remember (or look up) the fact that 1L is the same as 1000 mL – see figure 4.
Step 2: You are going from litres to millilitres, so you have to multiply by 1000.
Step 3: Work it out: The volume of the water is $0.125 \times 1000 = 125$ mL

EXAMPLE EXERCISE 2
An ammeter shows 82 mA. How many amps is that?

Step 1: Remember (or look up) the fact that 1 A is the same as 1000 mA.
Step 2: You are going from mA to A, so you have to divide by 1000.
Step 3: Work it out: The current = $\frac{82}{1000} = 0.082$ A

EXAMPLE EXERCISE 3
A cyclist's speed is 5.2 m/s. What is that in km/h?

Step 1: Remember (or look up) the fact that 10 m/s is the same as 36 km/h.
Step 2: You are going from m/s to km/h, so you are multiplying by 3.6.
Step 3: Work it out: The speed = $5.2 \times 3.6 \approx 19$ km/h

figure 4 As you can see from this measuring jug, 1 L is the same as 1000 mL.

5 Reading measuring instruments

When you make a measurement, you read off a measured value – a number – from a measuring instrument. This is easier for some measuring instruments than for others.

A digital measuring instrument such as a stopwatch or a digital clinical thermometer is electronic. The measured value is shown in numeric form on a screen. These types of meters make it very easy for you: all you have to do is write down the numbers.

An analogue measuring instrument such as a measuring cylinder or an analogue voltmeter uses a graduated scale. You read off a measuring cylinder by looking to see which mark the liquid level is at. For an analogue voltmeter, you look to see which mark the needle is pointing at.

For measuring instruments such as these, you cannot read off the measurement value immediately.
First, you have to know how much each mark represents. You can work that out as follows:

Step 1: **Go from the zero to the first numbered mark.**
In the measuring cylinder in figure 5, this is the line with a 20 next to it.

Step 2: **Go to the line half way between the zero and the first number.**
Work out what value belongs with this mark. For the measuring cylinder, that would be 10.

Step 3: **Now determine the value of each individual mark on the graduated scale.**
Count from 0 up to the first number to check that you've got it right.
For the measuring cylinder, it will work out correctly if you count in steps of 2 mL.

So each marker on the measuring cylinder represents 2 mL.
Confirm for yourself that this measuring cylinder contains 62 mL of water.

You can use the same method for other measuring instruments with graduated scales.

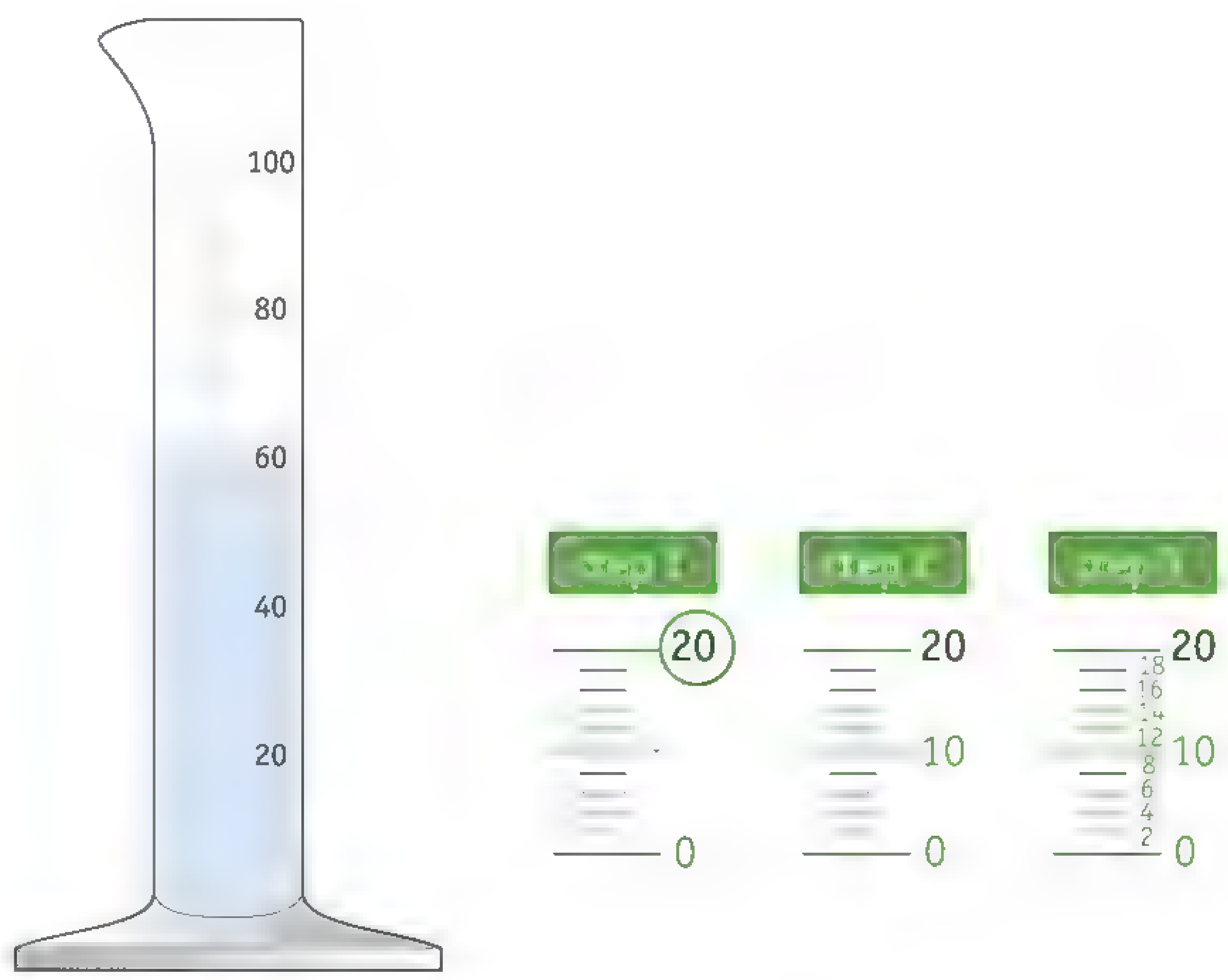


figure 5 How to read a measuring cylinder.

6 Working with a Bunsen burner

For physics and chemistry, you will sometimes use a Bunsen burner. The instructions below tell you how to use it.

Safety

- Stick to the safety rules that you have discussed with your teacher.

Before starting

- Check that the gas control knob and air control ring of the burner are closed (figure 6). If not, close them.

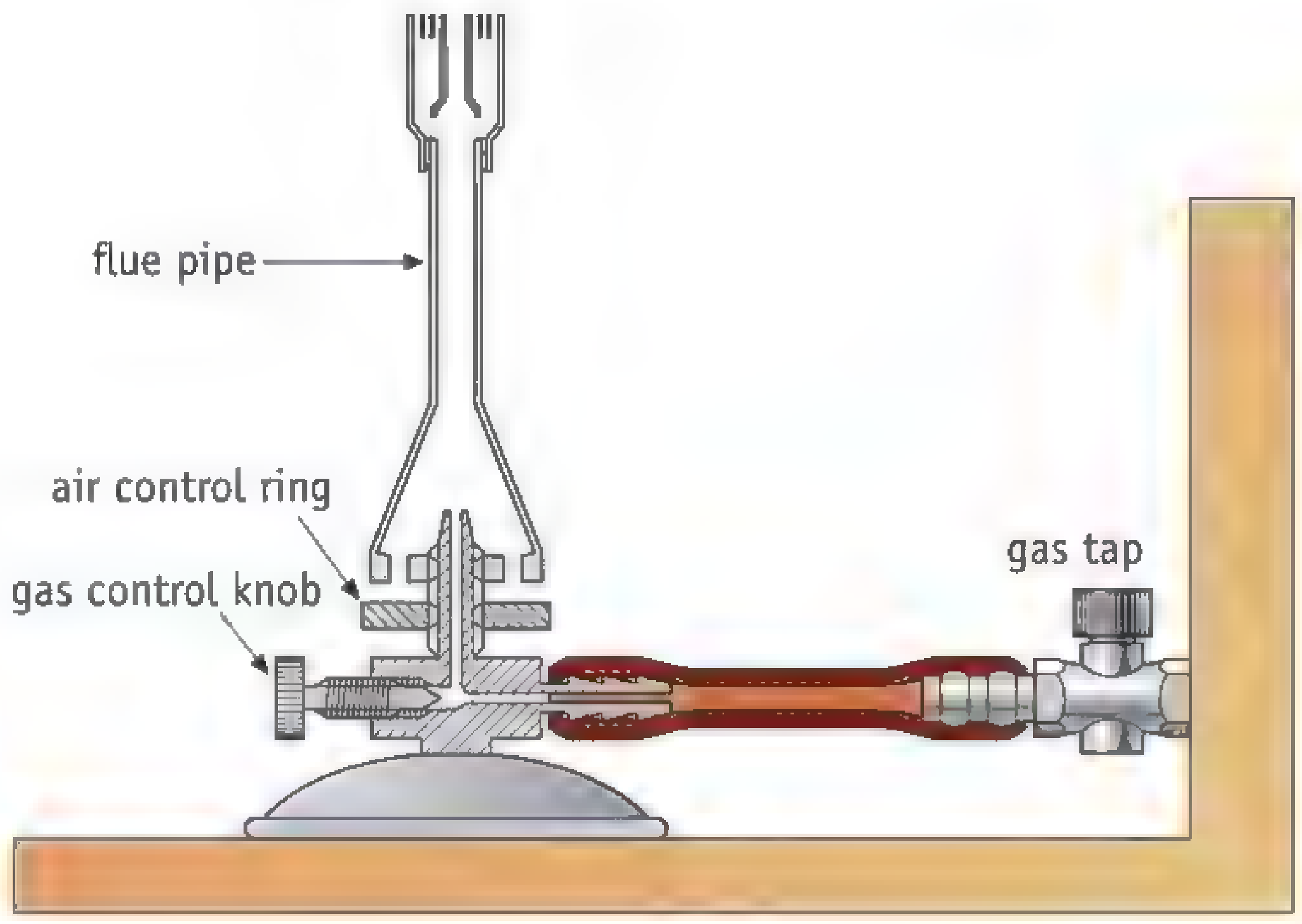


figure 6 The parts of a Bunsen burner.

Lighting

- Open the gas tap on your bench.
- Hold a lit match above the burner.
- Open the gas control knob.
- The burner will now burn with a clearly visible, yellow flame.

Heating

- Open the air control ring.
- The burner now burns with a poorly visible, blue flame. This blue flame is much hotter than the yellow flame. You generally use a quietly hissing, blue flame to heat things (never a yellow flame).

Interrupting an experiment

- Do not leave the Bunsen burner unattended when the flame is blue.
- Always close the air control ring first.
- The burner then burns with a clearly visible, yellow flame.

Turning it off

- Close the air control ring.
- Close the gas tap on your bench.
- Close the gas control knob.

7 Working with a voltmeter

Experiments with electricity often use a voltmeter. You must connect this kind of meter up correctly.

Connecting

- To measure the voltage across a bulb, you connect the voltmeter up in parallel with the bulb. See figure 7.
- Connect the positive terminal of the battery or power supply up to the positive connection on the voltmeter. The needle will then move in the right direction. If it nevertheless goes wrong, you should connect the two wires to the meter the other way around.

Measurement ranges

- Many voltmeters have various different measurement ranges. The meter in figure 7, for instance, has three measurement ranges: 0–3 volts, 0–15 volts and 0–30 volts. If you use the 0–3 volt measurement range, you can measure voltages up to a maximum of 3 volts.
- Do a test measurement first using the largest measurement range. This helps make sure that the meter will not get damaged. You can then see clearly whether or not you can use a smaller measurement range.
- You should then make the measurements using the smallest possible measurement range. The needle will then move further and you can read what it is showing more accurately.

Reading

- Always look at the meter as directly from the front as possible and do your best to read the value off accurately.

figure 7 How to connect up a voltmeter.

8 Working with an ammeter

Experiments with electricity often use an ammeter. You must connect this kind of meter up correctly (figure 8).

Connecting

- To measure the current through a bulb, you connect the ammeter in series with the bulb. The current flowing through the bulb then also has to flow through the meter.
- Connect the positive terminal of the battery or power supply up to the positive connection on the ammeter. The needle will then move in the right direction. If it nevertheless goes wrong, you should connect the two wires to the meter the other way around.

Measurement ranges

- The ammeter will usually let you choose from a number of different measurement ranges. The meter in figure 8 has three: 0-50 mA, 0-500 mA and 0-5 A. If you use the 0 to 500 mA measurement range, you can measure currents of a maximum of 500 mA.
- Do a test measurement first using the largest measurement range. This helps make sure that the meter will not get damaged. You can then see clearly whether or not you can use a smaller measurement range.
- Then do the measurement with a smaller measurement range if possible. If you can see that the current is about 30 to 40 mA, for example, you could switch down to the 0-50 mA range. The needle will then move a long way and you can read accurately what it is showing.

Reading

- Always look at the meter as directly from the front as possible and do your best to read the value off accurately.

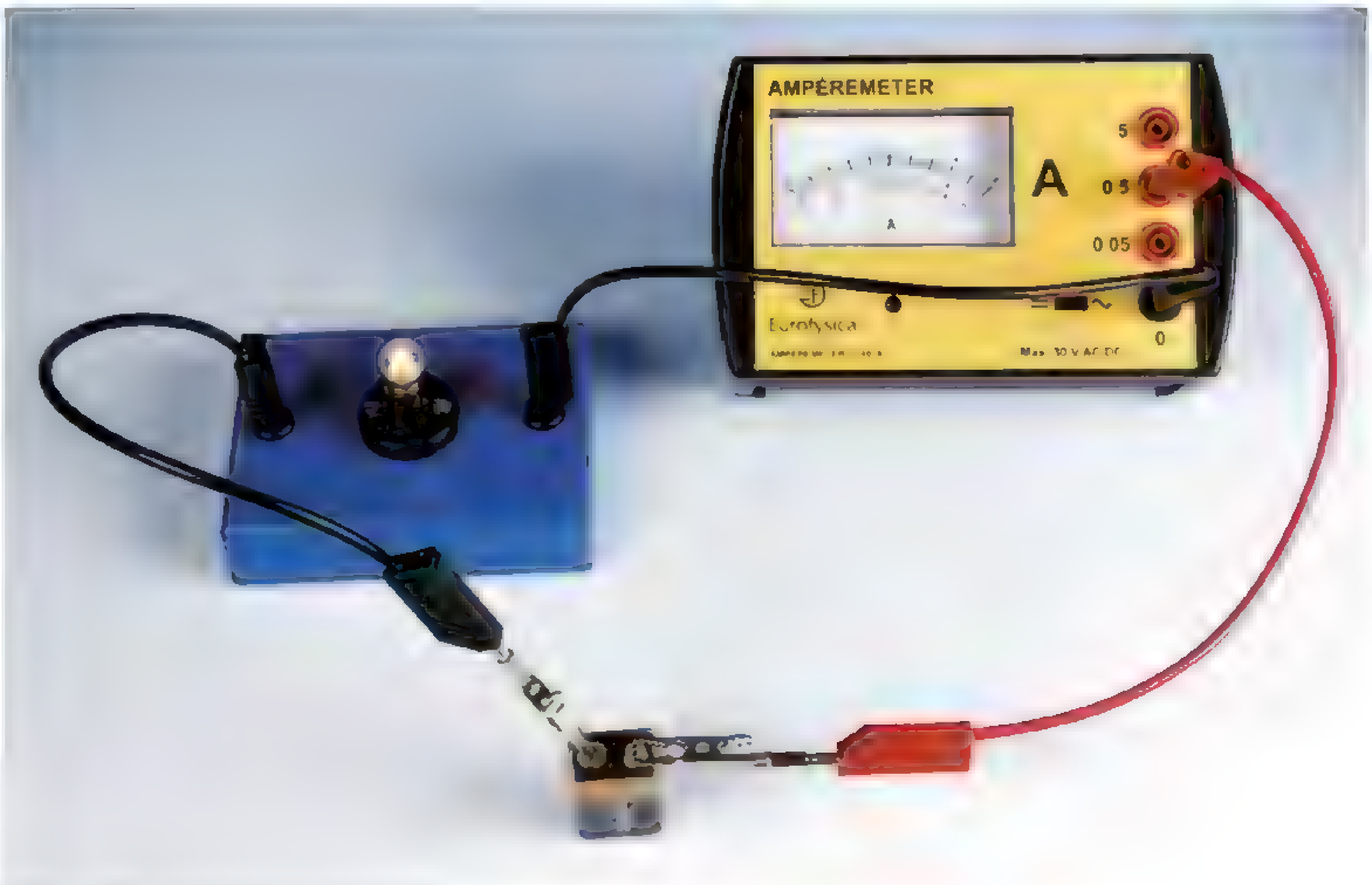


figure 8 How to connect up an ammeter.

9 Working with a multimeter

In experiments with electricity, you can use a multimeter instead of a voltmeter or an ammeter. There is a knob on the meter that makes it easy to choose the variable being measured and the desired measurement range (figure 9).

Measuring a voltage

- Turn the knob to the area marked "DCV" or "V=" and select the largest measurement range.
- Connect the multimeter up like a voltmeter: in parallel with the bulb.
- Make a test measurement. Repeat this if necessary using a smaller measurement range.
- Finally make the 'real' measurement using the smallest possible measurement range.

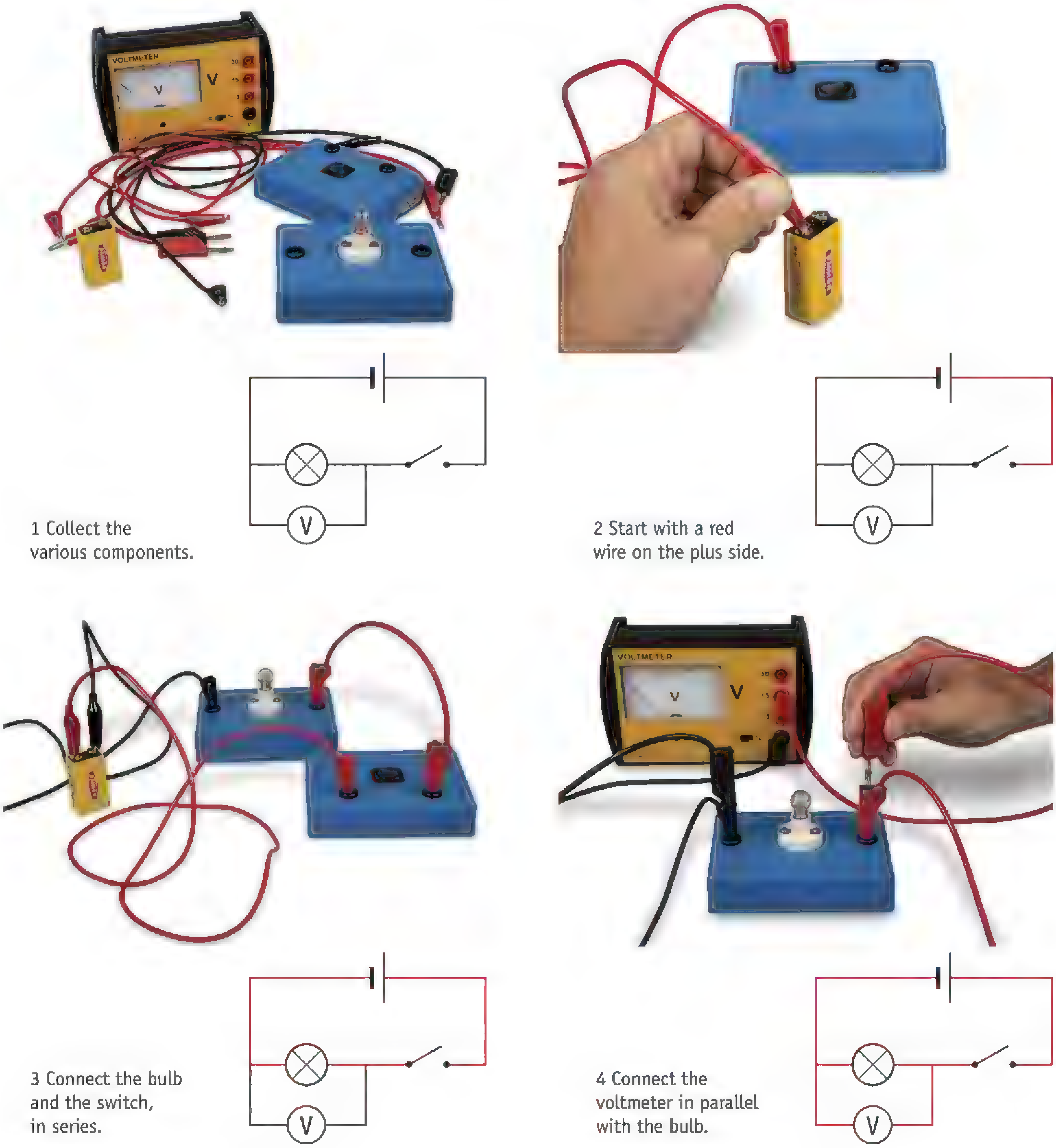
Measuring a current

- Turn the knob to the area marked "DCA or "A=" and select the largest measurement range.
- Connect the multimeter up like an ammeter, in series with the bulb.
- Make a test measurement. Repeat this if necessary using a smaller measurement range.
- Finally make the 'real' measurement using the smallest possible measurement range.

figure 9 A multimeter.

10 Building circuits

For some experiments, you use a circuit diagram to help put a circuit together. The best way to build a circuit is to do it step by step. Figure 10 shows you how.



1 Collect the various components.

2 Start with a red wire on the plus side.

3 Connect the bulb and the switch, in series.

4 Connect the voltmeter in parallel with the bulb.

figure 10 Building a circuit.

11 Working with an oscilloscope

An oscilloscope lets you determine the frequency of a tone. To do that, you first have to connect a microphone up to the input of the oscilloscope. The screen then shows a picture of the sound vibration.

The time base

The oscilloscope screen is subdivided into squares. Time is presented along the horizontal axis. If a single square is 2 milliseconds wide, we say that the time base is set to 2 milliseconds per division (2 ms/div). You can set the time base on the oscilloscope yourself.

Setting the time base

- Sometimes there will be too many vibrations on the screen at once. You should then set the time base to a smaller value.
- Sometimes all you can see is a small part of a single vibration. You should then set the time base to a larger value.
- The time base is set correctly if you can see just a few vibrations on the screen. You are then easily able to read off from the screen how much time is needed for a single vibration (figure 11).

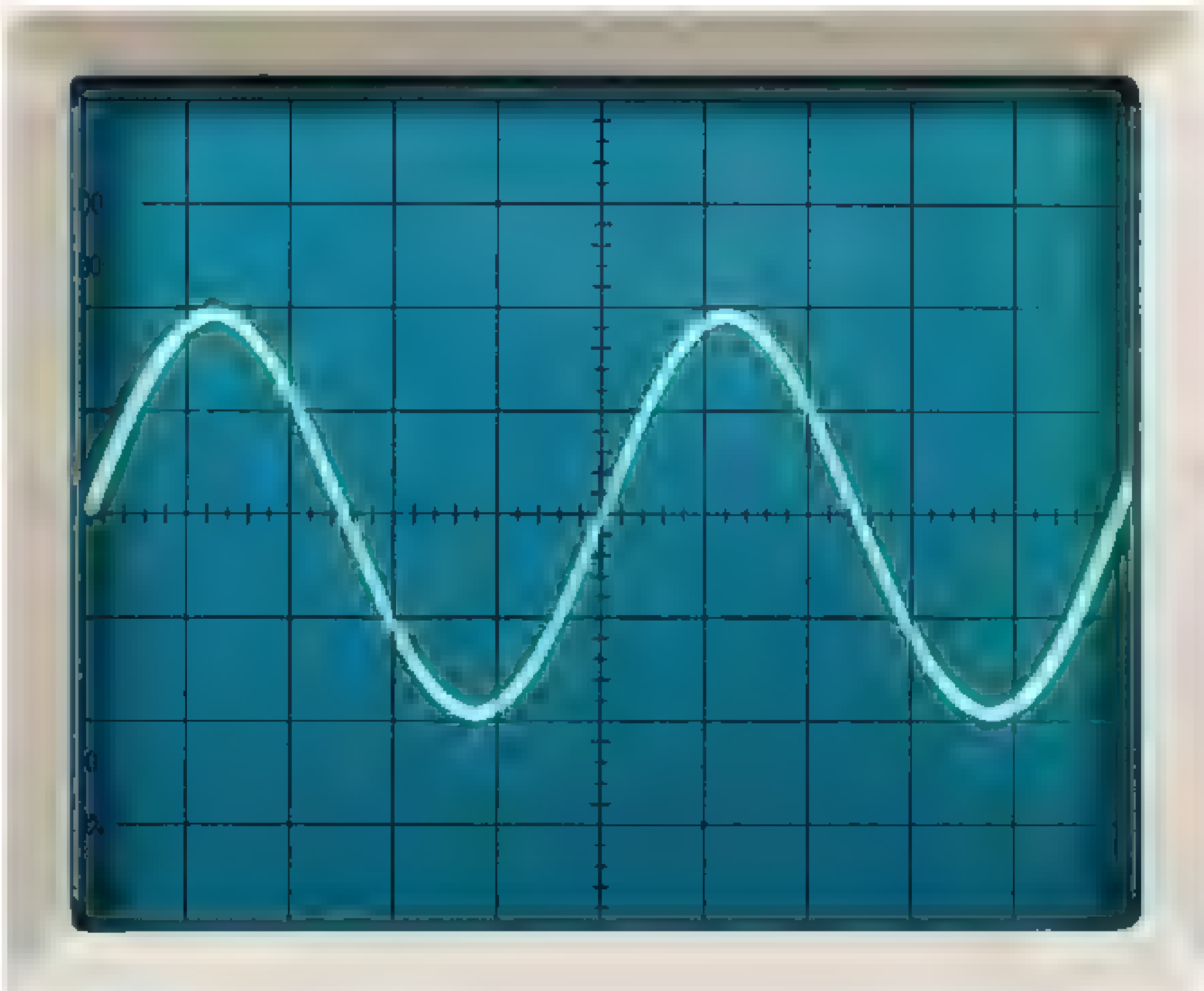


figure 11 An oscilloscope picture of a vibration.

EXAMPLE EXERCISE

The time basis for the oscilloscope in figure 11 is set to 2 ms/div (2 milliseconds per division).
Calculate the frequency of the vibration shown.

You can see that one complete vibration takes up five squares.
$T = 5 \times 2 \text{ ms} = 10 \text{ ms} = 0.01 \text{ s}$

$f = \frac{1}{T} = \frac{1}{0.01} = 100 \text{ Hz}$

On analogue oscilloscopes, you use a knob to set the time base (figure 12). On digital oscilloscopes, you can also set the time base yourself or you can press the auto-set button to let the oscilloscope find the most suitable time base (figure 13).

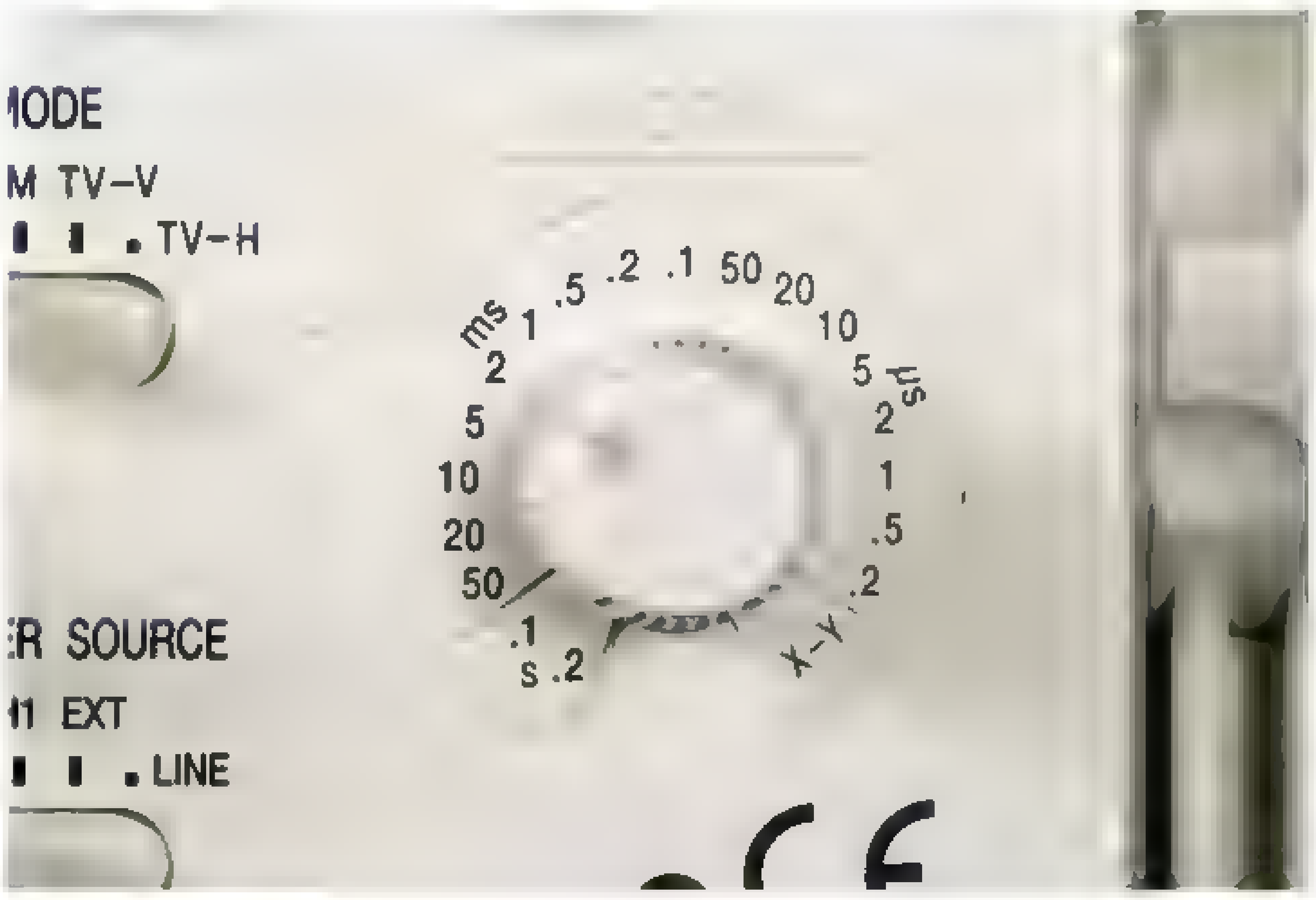


figure 12 The time base of an oscilloscope.

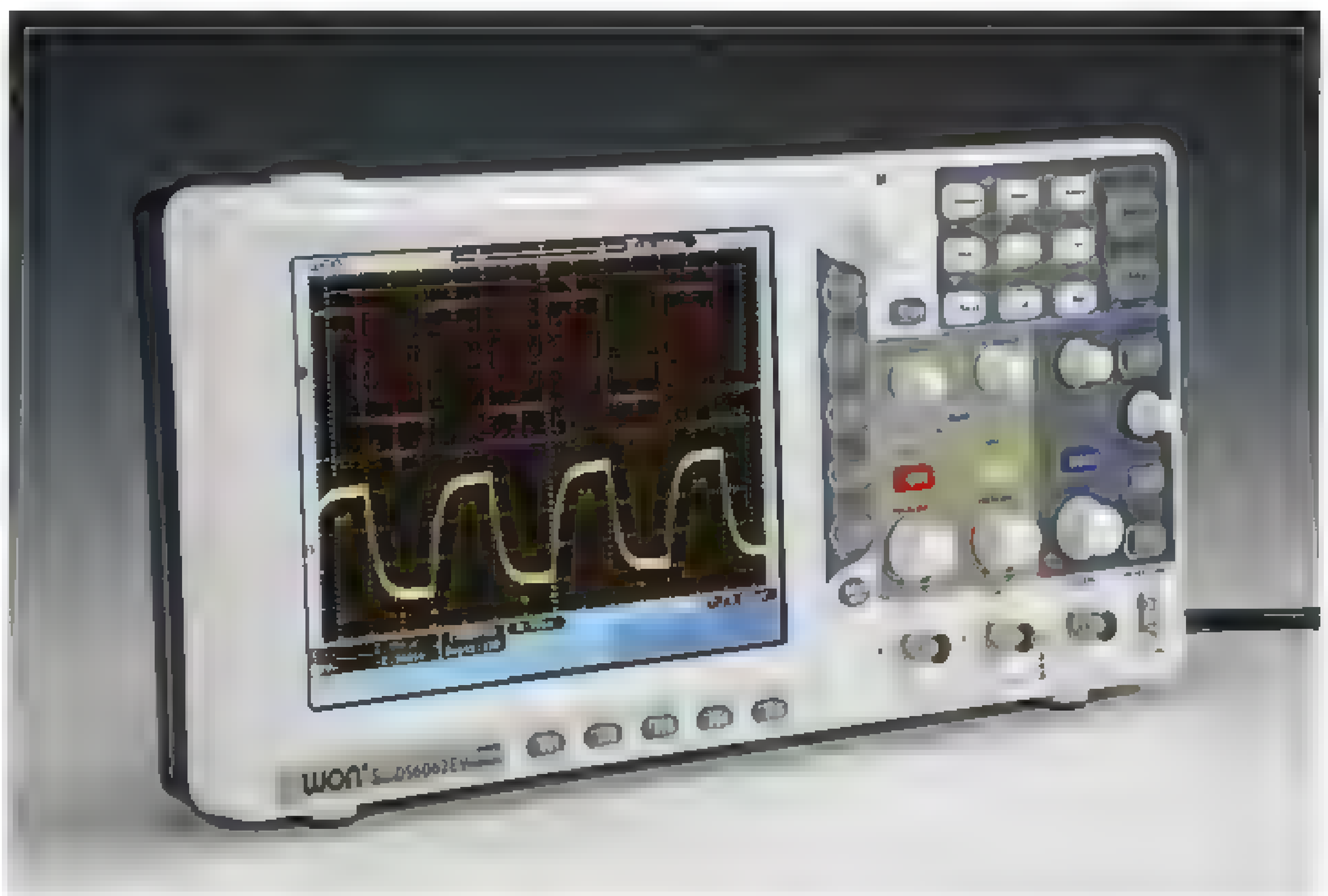


figure 13 A digital oscilloscope.

12 Working with formulae

For physics and chemistry, you will sometimes need to do calculations. You have to be able to show clearly how you got your answer.

You should therefore show the working for your calculations as follows:

Step 1: **Write down all the data you are using.**

Step 2: **Write down what you are being asked to find.**

Step 3: **Write down the formula in an appropriate form.**

You write down the formula for the power P as:

- $P = U \cdot I$ if you have to calculate the power P.
- $U = \frac{P}{I}$ to calculate the voltage U.
- $I = \frac{P}{U}$ to calculate the current I.

Step 4: **Fill in the data.**

Step 5: **Write down the answer, as a number followed by its units.**

Round the answer off if your answer would otherwise contain too many digits. A good rule of thumb is that your answer should have the same number of digits as (or at most one more digit than) the data item with the fewest digits.

EXAMPLE EXERCISE
A metal cylinder has a mass of 196 g and a volume of 22 cm^3.
Calculate the density of the material that the cylinder is made of.
What substance might it be?

given $m = 196$ g
$V = 22$ cm^3

required $\rho = ?$

working $\rho = \frac{m}{V} = \frac{196}{22} = 8.9$ g/cm^3

The cylinder could very well be made of copper: see table 1 in Section 4 of Chapter 2.

13 Working with tables and graphs

Many study questions are about the relationship between two variables. Take the following study question, for example:
What is the relationship between the temperature of water in a glass beaker and the time for which the water is heated?

This question is about the relationship between time and temperature. To answer the question, you carry out a series of measurements. You heat the water with a Bunsen burner. Once a minute, you read the water temperature from a thermometer. You then write down the measurement results in a table (see figure 14a). After completing the experiment, you show the measurement results in a graph. You make a graph as follows (see figures 14b, c and d):

Step 1: **Draw a set of axes.**

Step 2: **Label each axis with a variable and the corresponding units, for example 'time (min)' and 'temperature (°C)'.**

Step 3: **Draw an appropriate scale along each of the axes.**

Step 4: **Plot in the measurements as points.**

Step 5: **Draw a straight line or a smooth curve that fits the points as well as possible. You should not simply join the dots.** In other words, it doesn't matter if the straight line or curve does not go precisely through all the measurement points.

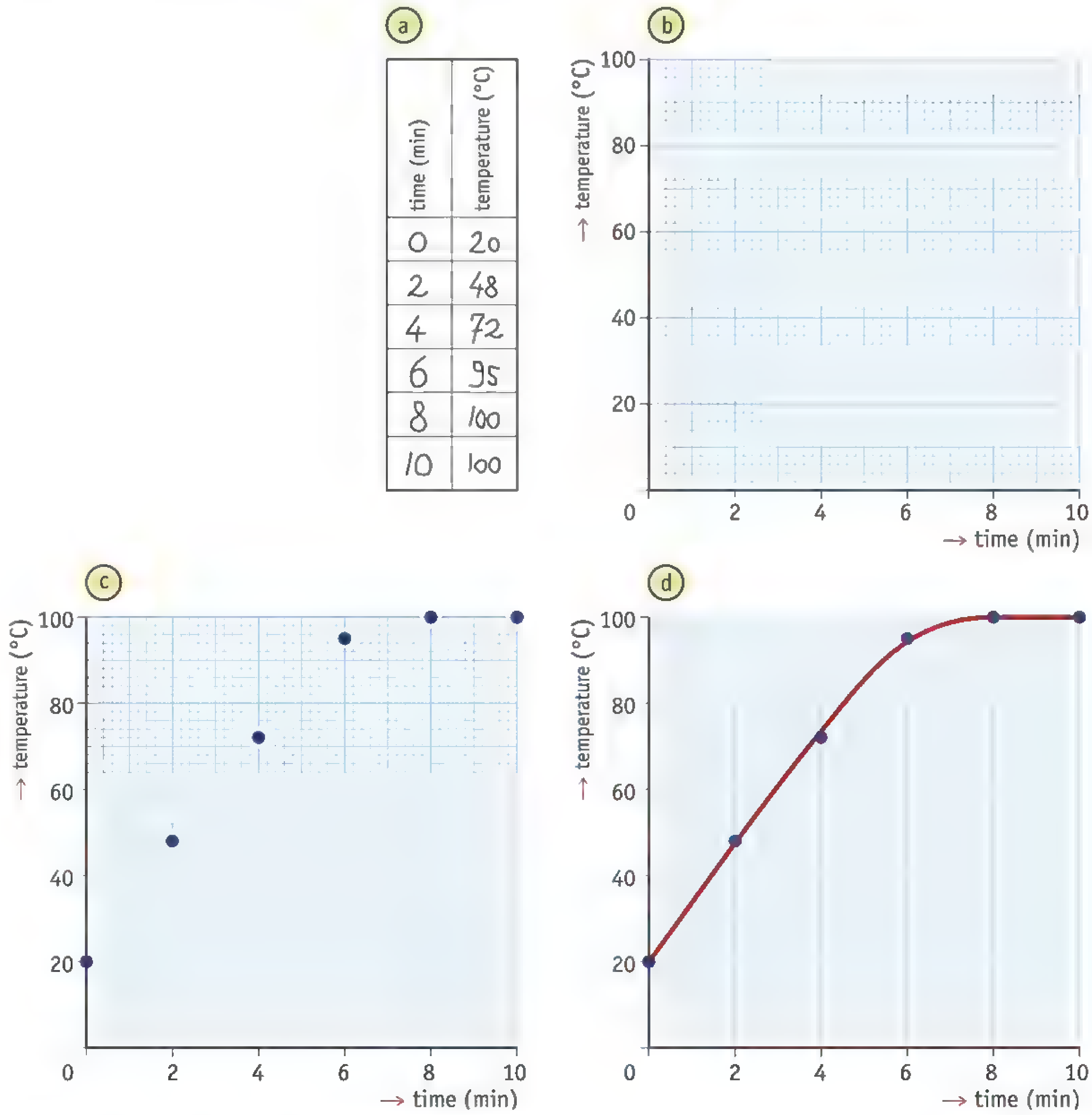


figure 14 From a table to a graph.

14 Writing a report

Research has to be written up. In the report, you explain what happened during the experiment. Somebody who was not actually there must be able to understand exactly what happened. Sometimes you also have to write a report of a practical experiment or a home assignment.

Lay your report out like this:

Title page
This is where you can give the title of the report, the names of the pupils in the group doing the experiment, the class, the name of your teacher and the date and year.

Section 1 Study question
This section is where you explain what question you wanted your study to answer.

Section 2 Working plan
This contains:
- a list of the things you used;
- a drawing of the experimental setup you made;
- a brief description of what you did.

Section 3 Experimental results
This is where you can state what you observed or measured. This can be in textual form or as tables, graphs, photographs and so forth.

Section 4 Conclusions
The answer to the study question can be stated here.

A report should look good. It is not only about the information that your report contains: you must also present that content clearly and neatly.

Glossary

A

air control ring luchtregelring
Onderdeel van de brander waarmee je meer of minder lucht bij het gas kunt laten.

ammeter stroommeter / ampèremeter
Instrument waarmee je kunt bepalen hoe groot de stroom door een stroomkring is.

analogue (measuring instrument) analoog (meetinstrument)
Meetinstrument met wijzers en een schaalverdeling.

B

barrel schoorsteen
Buis die boven op de luchtregelring van een brander staat, waarin lucht en gas gemengd worden.

biology biologie
Schoolvak dat de levende natuur bestudeert.

boiling koken
Het proces waarbij een vloeistof niet alleen aan de oppervlakte verdampt, maar overal in de vloeistof.

boiling point kookpunt
Temperatuur waarbij een vloeistof gaat koken. Het kookpunt is een kenmerkende stofeigenschap.

C

capillary tube stijgbuis
Doorzichtig pijpje van een thermometer waarin een vloeistof kan stijgen en dalen.

charge lading
Hoeveelheid elektriciteit. Een elektrische stroom bestaat uit lading die door de onderdelen van een stroomkring beweegt.

chemistry scheikunde
Schoolvak dat blijvende veranderingen in de niet-levende natuur bestudeert.

circuit stroomkring
Een geheel van geleidende delen van snoeren, lampen enzovoort, waar stroom doorheen kan lopen.

circuit diagram schakelschema
Een overzichtelijke tekening van een schakeling, weergegeven met symbolen.

condensation condenseren
Fase-overgang waarbij een stof overgaat van gasvormig naar vloeibaar.

conductor geleider
Stof waar een elektrische stroom gemakkelijk doorheen kan lopen.

crystal lattice kristalrooster
Regelmatige stapeling van moleculen van één stof. In dit rooster heeft elk molecuul een vaste plaats.

crystal structure kristalstructuur
Kenmerkende, regelmatige structuur van veel vaste stoffen.

current stroomsterkte
De hoeveelheid lading die per seconde voorbijkomt.

D

density dichtheid
De massa van 1 cm^3 van een stof.

deposition rijpen
Fase-overgang waarbij een stof overgaat van gasvormig naar vast.

digital (measuring instrument) digitaal (meetinstrument)
Met een digitaal meetinstrument meet je grootheden elektronisch. De meetwaarde wordt in cijfers (digits) op een scherm weergegeven. Bijvoorbeeld: een stopwatch of een digitale koortsthermometer.

digital thermometer digitale thermometer
Thermometer waarbij je de temperatuur op een schermpje kunt aflezen.

E

evaporation verdampen
Fase-overgang waarbij een stof overgaat van vloeibaar naar gasvormig.

experiment practicum
Het uitvoeren van experimenten bij natuurkunde en scheikunde.

extraction extraheren
Scheidingsmethode om oplosbare vaste stoffen te scheiden van niet-oplosbare vaste stoffen.

F

filtrate filtraat
De vloeistof die door het filter heen loopt tijdens het filtreren.

filtration filtreren
Scheidingsmethode om een vaste stof te scheiden van een vloeistof met behulp van een filter.

flammability brandbaarheid
Stofeigenschap die aangeeft hoe goed een stof kan branden.

freezing bevriezen
Een andere naam voor stollen, specifiek voor vloeistoffen die vast worden bij een temperatuur onder 0 °C.

freezing point vriespunt
Temperatuur waarbij een stof gaat stollen. Vries- en stolpunt zijn kenmerkende stofeigenschappen.

G

gas gas
Fase van een stof waarin alle moleculen los van elkaar kunnen bewegen. De moleculen zitten op relatief grote afstand van elkaar.

gas control knob gasregelknop
Onderdeel van de brander waarmee je meer of minder lucht bij het gas kunt laten.

graduated scale schaalverdeling
Streepjes op regelmatige afstand van elkaar met daarbij een reeks getallen waarmee je een meetwaarde kunt aflezen.

H

hazard symbol gevarensymbool
Een afbeelding (pictogram) die aangeeft voor welk gevaar je moet oppassen.

hypothesis hypothese
Voorlopig antwoord; de uitkomst die je vooraf voorspelt.

I

immersion method onderdompelmethode
Methode om het volume van een voorwerp met een onregelmatige vorm te bepalen.

indicator indicator
Een stof waarmee je de aanwezigheid van een andere stof kunt aantonen.

insulator isolator
Stof die een elektrische stroom niet of heel slecht doorlaat.

L

liquid vloeistof
Fase van een stof waarin alle moleculen langs elkaar heen kunnen bewegen. De moleculen zitten zo dicht mogelijk bij elkaar.

liquid thermometer vloeistofthermometer
Thermometer die bestaat uit een reservoir en een stijgbuis gevuld met vloeistof.

luminous flame pauzevlam
Geeloranje vlam van de brander.

M

mains voltage netspanning
De spanning die op stopcontacten staat. In Nederland is dit 230 V.

mass massa
Maat die aangeeft uit hoeveel stof een voorwerp bestaat.

measurement meetwaarde
Het getal dat bij de meting wordt bepaald.

measurement range meetbereik
Het verschil tussen de hoogste en de laagste temperatuur die je met een meetinstrument kunt meten.

measuring instrument meetinstrument
Gereedschap om te meten.

melting smelten
Fase-overgang waarbij een stof overgaat van vast naar vloeibaar.

melting diagram smeltdiagram
Grafiek die het temperatuurverloop tijdens het smeltproces weergeeft voor een specifieke stof.

melting point smeltpunt
Temperatuur waarbij een vaste stof gaat smelten. Het smeltpunt is een kenmerkende stofeigenschap.

mixture mengsel
Stof die uit twee of meer soorten moleculen bestaat.

molecules moleculen
Heel kleine deeltjes waar stoffen uit bestaan.

N

natural science natuurwetenschap
Wetenschap die de natuur bestudeert.

P

parallel circuit parallelschakeling
Een schakeling met meerdere stroomkringen.

particle model deeltjesmodel
Natuur- en scheikundig model dat ervan uitgaat dat stoffen uit moleculen bestaan.

phase transition fase-overgang
Een stof gaat van de ene toestand over in een andere toestand.

phases fasen
De drie toestanden waarin een stof zich kan bevinden: vaste stof, vloeistof en gas.

physics natuurkunde
Schoolvak dat tijdelijke veranderingen in de niet-levende natuur bestudeert.

power vermogen
De hoeveelheid elektrische energie die een apparaat per seconde verbruikt.

property of a substance stofeigenschap
Een eigenschap waaraan je een stof kunt herkennen en die je kunt gebruiken om stoffen te onderscheiden.

pure substance zuivere stof
Stof die uit één soort moleculen bestaat.

R

rechargeable battery herbruikbare batterij
Een batterij die je opnieuw kunt opladen.

research question onderzoeksvraag
Wat je wilt ontdekken tijdens het onderzoek.

reservoir reservoir
Ruimte onderaan de vloeistofthermometer die gevuld is met vloeistof.

residue residu
Deeltjes die achterblijven op het filter nadat alle vloeistof door het filter is gelopen.

roaring blue flame ruisende blauwe vlam
Heetste blauwe vlam van de brander die geluid maakt.

S

safety rules veiligheidsregels
Regels waar je je tijdens practicum aan moet houden.

science wetenschap
Het opdoen van kennis en het toepassen van die kennis in het dagelijks leven.

scientific method wetenschappelijke methode
Het doen van onderzoek volgens een aantal vaste stappen.

sense zintuig
Onderdeel van je lichaam waarmee je kunt waarnemen.

series circuit serieschakeling
Een schakeling die bestaat uit één stroomkring zonder vertakkingen.

silent blue flame stille blauwe vlam
Geluidloze blauwe vlam van de brander.

solid substance vaste stof
Fase van een stof waarin alle moleculen rond een evenwichtsstand trillen.

solidification diagram stoldiagram
Grafiek die het temperatuurverloop tijdens het stollingsproces weergeeft voor een specifieke stof.

solidifying stollen
Fase-overgang waarbij een stof overgaat van vloeibaar naar vast.

solution oplossing
Mengsel van twee (of meer) stoffen waarbij de opgeloste stof volledig is opgenomen in het vloeibare oplosmiddel.

source voltage bronspanning
De spanning van de spanningsbron, bijvoorbeeld een batterij.

study question onderzoeksvraag
Wat je wilt ontdekken tijdens het onderzoek.

sublimation vervluchtigen
Fase-overgang waarbij een stof overgaat van vast naar gasvormig.

suspension suspensie
Vloeistof waarin fijn verdeeld poeder zweeft.

switch schakelaar
Het onderdeel van een stroomkring waarmee je de stroomkring kunt openen of sluiten.

T

thermometer thermometer
Instrument om de temperatuur mee te meten.

total current totale stroomsterkte
De stroomsterkte in de onvertakte delen van een parallelschakeling.

transformer transformator
Apparaat dat netspanning omzet in een andere (meestal lagere) spanning.

U

unit eenheid
Maat waarin je iets uitdrukt.

V

variable grootheid
Eigenschap die je kunt meten.

voltage spanning
Een soort 'elektrische druk': hoe groter de spanning, hoe groter de 'druk' waarmee de lading door de stroomkring wordt gevoerd.

voltage source spanningsbron
Het onderdeel van een stroomkring dat de spanning levert. Bijvoorbeeld een batterij of een accu.

voltmeter spanningsmeter / voltmeter
Instrument waarmee je de spanning kunt meten.

volume volume
Maat voor de ruimte die een voorwerp of stof inneemt.

X

X-ray photographs röntgenfoto's
Foto's die worden gemaakt met behulp van röntgenstraling. Ze worden veel gebruikt om breuken in botten op te sporen.

Y

yellow flame pauzevlam
Geeloranje vlam van de brander.

Index

The page numbers after each concept tell you where it is explained in the lesson text and where it can be found in the course material overview.

Acknowledgements

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Pointer grafische vormgeving
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IMAGE JUSTIFICATION
123RF/costasz: Pag. 45 (o.); 123RF/Vladimir Soldatov: Pag. 122/123; ANP Foto/Huisman Media: Pag. 16; ANP Foto/ Science Photo Library/Dirk Wiersma: Pag. 55; ANP Foto/ Science Photo Library/Scientifica/Visuals Unlimited: Pag. 91; ANP Foto/Science Photo Library: Pag. 12; ANP/Brenton Edwards: Pag. 163 (o.); ANP/Science Photo Library/Detlev van Ravenswaay: Pag. 97 (o.); Bounce Pro/Sports Power: Pag. 11 (o.); Can Stock Photo Inc./AnnieAnnie: Pag. 57; Corbis/Getty Images/Bo Zaunders: Pag. 90 (b.); Corbis/Getty/Vincon/ Klein/plainpicture/123RF: Pag. 100 (o.); Creative Commons/ Jorrit Lousberg: Pag. 164, 165; Depositophoto, San Francisco: Pag. 175; Edwin Verbaal/Verbaal Visuele Communicatie, Arnhem: Pag. 87 (b.), 87 (o.), 89 (l.), 89 (r.), 90 (o.), 94, 95 (o.), 98, 101 (b.), 106, 109, 116 (b.), 118; Erik Eshuis Infographics, Groningen: Pag. 13, 19 (b.), 20 (o.), 22, 23 (m.), 25, 26, 30, 38, 81 (o.), 124, 125 (o.), 127, 130 (r.o.), 130 (l.o.), 131, 132 (r.b.), 136 (b.), 136 (o.), 137 (o.), 139, 140 (b.), 140 (b.), 140 (l.m.), 140 (r.m.), 140 (o.), 141 (l.b.), 141 (r.b.), 141 (o.), 146, 147 (b.), 149 (b.), 151, 152, 153, 168; Eurofysica: Pag. 183 (r.b.); EyeEm Mobile GmbH/Hollandse Hoogte/ Karol Wójcik: Pag. 34/35; Fundamental Photographs/Richard Megna: Pag. 85; Gate House Media/Penn State University, RF: Pag. 104 (o.); Getty Images/Cameron Spencer: Pag. 73; Getty Images/Eric PASQUIER/GAMMA-RAPHO: Pag. 51; Getty Images/Kraft Angerer: Pag. 116 (o.); Getty Images/Science Photo Library: Pag. 43 (l.b.); Hollandse Hoogte/Berry Stokvis: Pag. 75 (l.), 75 (r.); Hollandse Hoogte/Bert Van den Broucke - Philip Reynaers: Pag. 134; Hollandse Hoogte/Joyce van Belkom: Pag. 172; Hollandse Hoogte/Richard Brocken: Pag. 36 (b.); Hollandse Hoogte/Sven Torfinn/Panos Pictures: Pag. 150; Image Bank Collection Getty Images RF/mycola: Pag. 97 (b.); Jacob breimer, Zeeland NB: Pag. 135 (l.b.), 135 (r.b.), 135 (o.), 45 (b.), 47 (r.o.), 170; Merlijn Michon Fotografie, Amsterdam: Pag. 15, 48 (r.o.), 100 (b.), 100 (m.), 105, 128

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Cover

RooM the Agency/Alamy Stock Photo/Imageselect

ISBN 978 94 020 6900 6

Release 2021, eerste oplage

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ISBN 978 94 020 6900 6

9 789402 069006

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